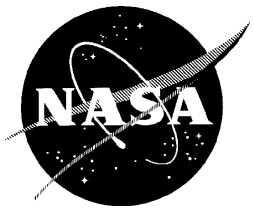
APPLIED ENGINEERING AND TECHNOLOGY DIRECTORATE

Detailed Mission Requirements (DMR) for the Triana Mission

February 2000



National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

1010-1

Approval Authority

AUTHORITY (REFERENCES)

a. Project Initiation Agreement

b. Execution Phase Project Plan (Triana)

c. NASA Management Instruction (NMI) 8430.1C

d. Triana Project Service Level Agreement (PSLA)

Project Center(s)		Support Center(s)	
11. Requirements Prepared By: John J. Catena Triana Ground Systems Project Manager/Code 581 Goddard Space Flight Center	Date 11/22/99	12. Responses Prepared By: Robert Schweiss Triana Implementation Manager Code 586 Goddard Space Flight Center	Date 11/23/99
13. Approved By: Tim Trenkle Triana System Engineer Code 474 Goddard Space Flight Center	Date 11/23/99	14. Concurred By: Allen L. Berman Telecommunications and Mission Services Manager Jet Propulsion Laboratory	Date 1/13/00
15. Approved By: James G. Watzin Triana Program Manager Code 474 Goddard Space Flight Center	Date 2/14/00	16. Approved By: Douglas G. Griffith Center Mission Services Manager Division 920 Jet Propulsion Laboratory	Date 2/9/00

1030-1

Revision Approval

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3110	0	4322	0		
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Change Approval

Project Center(s)		Support Center(s)	
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1061-1

Term	Definition
ACS	Attitude Control System
AETD	Applied Engineering and Technology Division
AO	Announcement of Opportunity
AOS	acquisition of signal
APID	Application Process Identifier
ASCII	American Standard Code for Information Interchange
ASE	Airborne Support Equipment
bps	bits per second
BPSK	biphase shift keying
C&DH	command and data handling
CAS	calibrated ancillary system
CCB	Configuration Control Board
CCL	closed-circuit loop
CCSDS	Consultative Committee for Space Data Standards
CDR	Control Data Recording
CDHF	Central Data Handling Facility
CH	computational hub
CLCW	command link control word
CLTU	command link transmission unit
CMD	command
COP	Command Operating Procedure
CPIO	copy in/out
CY	calendar year
DAAC	Distributed Active Archive Center
dbW	decibel watts
dB	decibel
dBi	decibel isotropic
dBm	decibels referenced to 1 milliwatt of power

DEL	Data Evaluation Laboratory
DMR	Detailed Mission Requirements
DSN	Deep Space Network
DTAS	Data Trending and Analysis System
EIRP	Effective Isotropic Radiated Power
EOM	end of mission
EPIC	Earth Polychromatic Imaging Camera
ER	Eastern Range
ESA	electrostatic analyzer
ETE	end-to-end
ETU	engineering test unit
EU	engineering unit
FARM	Frame Acceptance Reporting Mechanism
FDD	Flight Dynamics Division
FDF	Flight Dynamics Facility
FDSS	Flight Dynamics Support System
FF	fill frame
FIFO	first-in-first-out
FSM	flight software maintenance
FSME	flight software maintenance equipment
FSMF	Flight Software Maintenance Facility
FSWM	Flight Software Maintenance
FTP	File Transfer Protocol
GDS	Ground Data System
GM	ground monitor
GS	ground station
GSE	ground support equipment
GSFC	Goddard Space Flight Center
GSPM	Ground Systems Project Manager
HGA	high-gain antenna

I&T	integration and test
I/F	interface
ICD	interface control document
ID	identification
IGSE	instrument ground support equipment
IIRV	improved inter-range vector
IM	Implementation Manager
IONET	IP Operational Network
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISTP	International Solar-Terrestrial Physics
ITOS	Integrated Test and Operations System
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
kbps	kilobits per second
kHz	kilohertz
km	kilometer
KSC	Kennedy Space Center
kW	kilowatt
L	launch
L&EO	launch and early orbit
LaRC	Langley Research Center
LHCP	Left Hand Circular Polarization
LOS	loss of signal
LPRL	Lockheed Martin Palo Alto Research Laboratory
LRR	Launch Readiness Review
LV	launch vehicle
L1	Earth-Sun Lagrange point
MAP	multiple access point
MB	megabyte

MBps	megabytes per second
MHz	megahertz
MCC	maneuver course correction
MMFD	Multi-Mission Flight Dynamics
mm	millimeter
MOC	Mission Operations Center
MOR	Mission Operations Room
MOSA	Mission Operations Support Area
MOT	Mission Operations Team
MP	Mission Planner
MRM	Mission Readiness Manager
MRT	Mission Readiness Test
MRTM	Mission Readiness Test Manager
MRTP	Mission Readiness Test Plan
MRTS	Mission Readiness Test Section
MRTT	Mission Readiness Test Team
N/A	not applicable
NASA	National Aeronautics and Space Administration
Nascom	NASA Communications
NISN	NASA Integrated Services Network
NIST	National Institute of Standards and Technology
NISTAR	National Institute of Standards and Technology Advanced Radiometer
NMC	Network Management Center
NMI	NASA Management Instruction
NOAA	National Oceanic and Atmospheric Administration
NRT	nonreal time
NRZ-L	nonreturn to zero level
NSSDC	National Space Sciences Data Center
OA	Operations Agreement
OBC	onboard computer

Ops	operations
PDB	Project Data Base
PI	principal investigator
PIP	Payload Integration Plan
PlasMag	plasma/magnetometer (payload)
PM	phase modulation
POCC	Payload Operations Control Center
PSK	phase shift keying
PSLA	Project Service Level Agreement
R/T	real time
rad	radian
RAM	Random Access Memory
REP	regular event processor
RF	radio frequency
RGB	red, green, blue
RGS	remote ground station
S/C	spacecraft
S/W	software
SAMPEX	Solar Anomalous and Magnetospheric Particle Explorer
SCAMA	switching, conferencing, and monitoring arrangement
SCID	spacecraft identifier
SCP	stored command processor
SCS	Spacecraft Computer System
SDVF	Software Development and Validation Facility
SERS	Spacecraft Emerging Response System
SFDU	Standard Formatted Data Unit
SIM	simulation
SM	system monitor
SMEX	Small Explorer
SN	Space Network

SOC	Simulation Operations Center
SOMO	Space Operations and Management Office
SPICE	Spacecraft, Planet, Instrument, C-matrix, Events
SPIF	Shuttle-POCC Interface Facility
SPK	SP Kernel (Spacecraft, Planet Kernel)
STOL	Spacecraft Test and Operations Language
STS	Space Transportation System
SWAS	Submillimeter Wave Astronomy Satellite
T&C	telemetry and command
TBD	to be defined
TC	telecommand
TCP	Transmission Control Protocol
TLM	telemetry
TMOD	Telecommunications Management and Operations Directorate
TMS	Telecommunications and Mission Services
TRACE	Transition Region and Coronal Explorer
TRK	tracking
TSOC	Triana Science Operations Center
TT&C	telemetry tracking and command
UDP	user datagram protocol
UPS	uninterrupted power supply
USN	Universal Space Network
UTC	Universal Time Coordinated
UTDF	Universal Tracking Data Format
UV	ultraviolet
V/T	Voltage/Temperature
VC	Virtual Channel
VCID	virtual channel identifier
VIS	visible
VMOC	Virtual Mission Operations Complex

VPN	Virtual Private Network
WFF	Wallops Flight Facility
WIRE	Wide-Field Infrared Explorer
WOW	weight on wheels
WS	workstation
WSC	White Sands Complex

1064-1

Responsibilities for Management, Project, and Operations

Program Center – Goddard Space Flight Center (GSFC) is responsible for overall project management.

Program Directorate – Within GSFC, responsibility for the Triana mission has been assigned to the Flight Projects Directorate, Code 400, to plan, implement, and coordinate development of the mission.

Program Manager – Mr. James Watzin is the Triana Program Manager, and is responsible for ensuring the performance of all functions necessary for the management of all Triana Project mission responsibilities.

Deputy Program Manager – Mr. Craig Tooley is the Triana Deputy Program Manager, and is responsible for the overall performance and accomplishment of Triana mission goals.

Triana Principal Investigator (PI) – Dr. Francisco Valero, Scripps Institute of Oceanography, is the PI for the Triana mission, and is responsible for ensuring the satisfactory accomplishment of the science objectives.

Ground Systems Project Manager (GSPM) – Mr. John J. Catena is the GSPM for the Triana Project, and is responsible for the development and implementation of mission operations requirements for both space and ground segments during all phases of the Triana mission. Following launch, the GSPM shall conduct the flight operations activities to fulfill the mission objectives.

Implementation Manager (IM) – Mr. Robert Schweiss is the IM, and is responsible for accepting project requirements, directing requirements to the appropriate elements of the Applied Engineering and Technology Division (AETD), obtaining and implementing the commitment of AETD resources, and overseeing the planning, implementation, and operation of AETD support.

Jet Propulsion Laboratory (JPL) – Allen Berman is the Deep Space Network (DSN) Telecommunications and Mission Services (TMS) Manager, and is responsible for all DSN support to the Triana Project.

Universal Space Network (USN) – Mr. Jay Heberle, Mission Operations Manager, is the principal point of contact with USN, and is responsible for all USN support to the Triana Project.

1066-1

The Triana telemetry and command data systems shall comply with the Consultative Committee for Space Data Systems (CCSDS).

1100-1

Project Description

The Triana mission will use a spacecraft bus design based on the SMEX-Lite spacecraft bus architecture developed by the Small Explorer (SMEX) Project at the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC). The spacecraft has been designed as a single-string system. A system design has been selected that uses proven design concepts derived from the Submillimeter Wave Astronomy Satellite (SWAS), Transition Region and Coronal Explorer (TRACE), and Wide-Field Infrared Explorer (WIRE) missions. Triana is a 2-year mission with enough consumables onboard for an additional 3 years.

The primary objective of the Triana mission is to provide continuous, long-range Earth observations at a unique perspective, the Earth-Sun Lagrange point (L1). In addition, a complement of solar weather-monitoring instruments will provide additional information on space conditions at the Triana location. The specific science objectives of Triana are to (1) measure the radiant power of the Earth's reflected light, (2) observe the Earth's vegetation canopy structure and evolution, and (3) measure solar radiation at the L1 location.

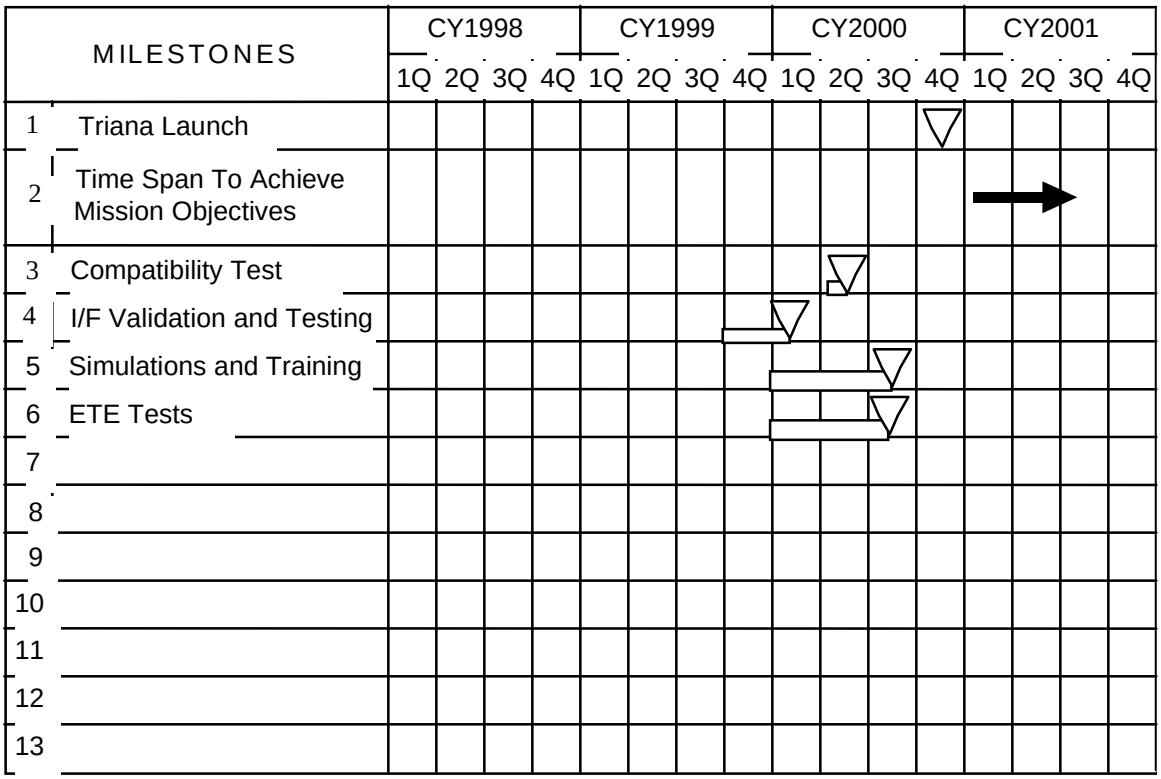
Triana will be a pathfinder mission for the next generation of Earth remote-sensing instruments. The L1 vantage point with its full-disk view of the Earth enables retrieval of global quantities at once, whereas measurements from low-Earth orbit and geostationary-Earth orbit must be merged together, requiring concerted efforts to process out differences due to viewing times and revisit intervals.

The Triana orbit was selected so that the spacecraft will have a full sunlit view of the Earth at all times. The spacecraft will be carried aboard the Shuttle and deployed shortly after the Shuttle achieves orbit. A kick-motor stage will send the spacecraft to the L1 vicinity where onboard thrusters will insert the spacecraft in a 2- to 15-degree Lissajous orbit about the L1 point. Periodic maneuvers will maintain the orbit over potentially 5 years.

Triana will contain three instruments. The main observation instrument is the Earth Polychromatic Imaging Camera (EPIC), which will be built at the Lockheed Martin Advance Technology Center located at the Lockheed Martin Palo Alto Research Laboratory (LPARL). The second Earth-observing instrument is the National Institute of Standards and Technology Advanced Radiometer (NISTAR). The third instrument payload is called the plasma/magnetometer (PlasMag) instrument, which includes three separate sensors: a Faraday cup, a magnetometer, and an electrostatic analyzer (ESA).

1105-1

Planned Mission Milestones



1110-1

Instruments

As stated in Section 1100-1, Project Description, the Triana payload consists of three instrument groups. The primary payload is the EPIC, the second Earth-observing instrument is the NISTAR, and the solar weather-monitoring payload is the PlasMag field experiment instrument.

Detailed information on the instruments is available from the Triana mission Web site at http://triana.gsfc.nasa.gov/home/.

1120-1

Operations Concept

All Triana flight operations are performed using support facilities operated by the AETD, Code 500. These ground facilities provide support for commanding and telemetry routing; communications; testing; simulations; orbit and attitude computation and accuracy verification; command management; and science data capture, processing, and distribution. The Mission Operations Center (MOC) is the focal point of on-orbit operations and is manned up to 8 hours a day, 5 days a week, by the Mission Operations Team (MOT) during normal operations.

1120-1.1

Functional Elements

The Triana ground system architecture is shown in Figure 1120-1. The AETD provides four key elements to support the Triana mission: the MOC, consisting of the Integrated Test and Operations System (ITOS), the command station, Flight Dynamics Support System (FDSS), and Data Trending and Analysis System (DTAS); the NASA Integrated Services Network (NISN); and the Mission Operations Support Area (MOSA). The AETD also provides the MOT to operate the Triana spacecraft from prelaunch through the end of the mission.

Additional functional elements for the Triana mission include the ground stations, the Simulations Operations Center (SOC), and the Eastern Range (ER) launch site.

MOC Real-Time Systems

The MOC real-time systems include the ITOS. The ITOS generates commands initiated by MOT or principal investigator (PI) input and forwards them to the ground stations via NISN for uplink. It also receives the stripped Virtual Channel 0 (VC0) containing engineering data from the ground stations through NISN. Decommutation, calibration, and limit checks are performed on the engineering telemetry stream. The ITOS also performs Level 0 processing of EPIC data, including data quality checking and short-term data storage.

The principal MOT functions are to maintain the health, safety, and performance of the spacecraft, and support investigator activities. The real-time systems are the primary MOT interface for command and control, and spacecraft health and safety monitoring.

MOC Offline Systems

The MOC offline systems include the command station, the FDSS, and the DTAS. The command station receives spacecraft and payload scripts and converts them into executable program language for upload to the spacecraft command and data handling (C&DH) software system. The station receives input from the MOT, FDSS, Triana Science Operations Center (TSOC), and Triana Project. The FDSS provides attitude determination, attitude control, and trajectory support. The DTAS provides data trending functions, including long-term storage of selected spacecraft telemetry, data analysis, and plotting capabilities.

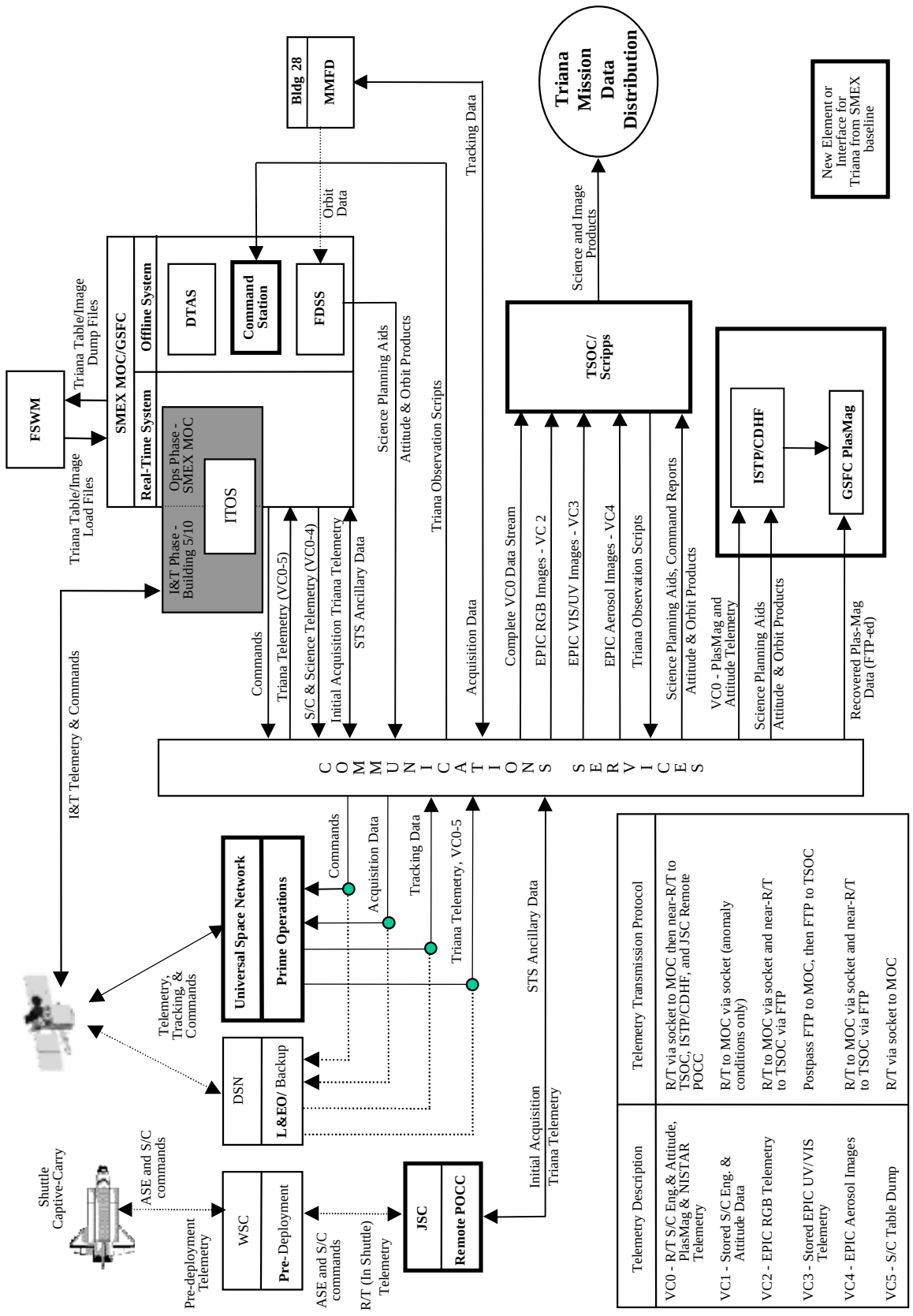


Figure 1120-1: Triana Ground Data System Architecture Diagram

NASA Integrated Services Network

NISN provides the voice and data communication circuit interfaces among the supporting elements. Communication services are required to support operations activities during prelaunch, launch, and postlaunch mission operations.

Ground Stations

Primary communications between the spacecraft and the ground facilities are provided through a dedicated commercial ground station network, the Universal Space Network (USN). NASA resources will supplement the prime network. These resources include the DSN ground stations at Madrid, Spain, Canberra, Australia, and Goldstone, California, for supplemental support to the USN during initial mission phases from spacecraft deployment from the Space Transportation System (STS), through cruise to on-orbit insertion. Contingency support may also be required by all identified DSN locations during all phases of the mission up to on-orbit insertion on a network availability basis and as network scheduling of resources allows. In addition, Canberra will be required for backup to the USN during normal operations support and all stations for emergency operations.

Triana Science Operations Center

The Scripps Institute for Oceanography at La Jolla, California, is the principal science operations and analysis center. It is provided by the science community, which interfaces with the Triana Project and GSFC ground elements to conduct the science mission. The TSOC will operate 5 days a week, primarily performing science planning, data analysis, and data distribution. The center will also provide the instrument commands to the MOC.

Launch Site

Mission operations activities at the Kennedy Space Center (KSC) launch site require communications to support integration testing, end-to-end (ETE) testing, operation simulations, and launch. Voice and data communications are required between the launch site and GSFC.

1120-1.2

Operational Phases

Prelaunch Processing and Launch Operations

After arrival at the launch site, receiving inspections are performed. Functional testing of the spacecraft is performed to ensure the spacecraft and instrument interfaces and systems are functioning properly and as designed following shipment.

Shuttle Deployment

Refer to the *Payload Integration Plan (PIP) for Triana*, NASA/Johnson Space Center (JSC) document for Shuttle deployment information. It is available online at the Tirana Web site.

Cruise and Orbit Insertion Phase

The Triana spacecraft will be launched using the NASA Space Shuttle. Once deployed from the Shuttle, an expendable booster rocket will engage and place the spacecraft on course for L1 orbit insertion. Upon completion of the booster rocket burn, the spacecraft will separate from the booster and automatically deploy the solar panels and turn on the transponder.

On the first day of the mission, Triana will use onboard thrusters to perform the first maneuver course correction (MCC-1), which will be a series of burns to correct for residual effects of the initial booster burn. At L+60 days, MCC-2 will place the spacecraft on a trajectory for L1 insertion. At L+120 days, MCC-3 will occur to place the spacecraft in the 2- to 15-degree Lissajous orbit about the L1 location. During the cruise phase, science instruments will be activated and undergo periodic calibration slews. Science data will be collected and downlinked to the ground data system for processing.

Normal Operations

During normal operations, the science operations center provides instrument command scripts to the command station. The scripts are converted into a command load for uplink by the MOT. In addition, spacecraft-related commands and data are incorporated by the MOT to accommodate spacecraft bus operations.

Continuous space-to-ground support is required for Triana mission operations. The supports are scheduled by the commercial network provider for dumping science and engineering data from the spacecraft's solid-state recorder, uplinking the stored command loads, and verifying the spacecraft's health and safety. The DSN will be used only during contingency situations.

Lights-Out Operations

Lights-out operations refers to all spacecraft and ground operations activities that are conducted autonomously by software and hardware systems of the MOC without the presence of the MOT. The staffing profile is for the MOT to operate the MOC 24 hours per day during the launch, deployment, and initial cruise phases (~10 days). Following this phase, partially manned staffing occurs until the commencement of orbit insertion activities. During this time, the MOT will manually perform all spacecraft loads and dumps.

The transition to lights-out operations will occur sometime after the commencement of normal operations. The MOT will transition to a 12-hour-per-day staffing level. During this period, most spacecraft loads and dumps will still be performed manually by the MOT, while some loads and dumps will be performed using the autonomous pass tools with the MOT present, in preparation for subsequent lights-out operations.

After normal operations have become routine, the MOT will move to an 8-hour-per-day, 5-day-per-week staffing profile, during which lights-out operations will include autonomous spacecraft commanding and load uplink on a regular basis during unmanned shifts. On weekends, both activities will be performed in the blind.

1310-1

Refer to the *PIP for Triana,* NASA/JSC document for launch site and Shuttle requirements, configurations, and descriptions. This document is available online at the Triana Web site.

1320-1

Spacecraft Description

The Triana spacecraft is a three-axis inertial pointer. Triana will maintain instrument and solar array Sun pointing. The Triana instruments will interface with the spacecraft as a fully assembled module. Triana has six main subsystems:

a. Attitude and Orbit Control Systems

b. Command and Data Handling (C&DH)

c. Electrical Power

d. Propulsion Module

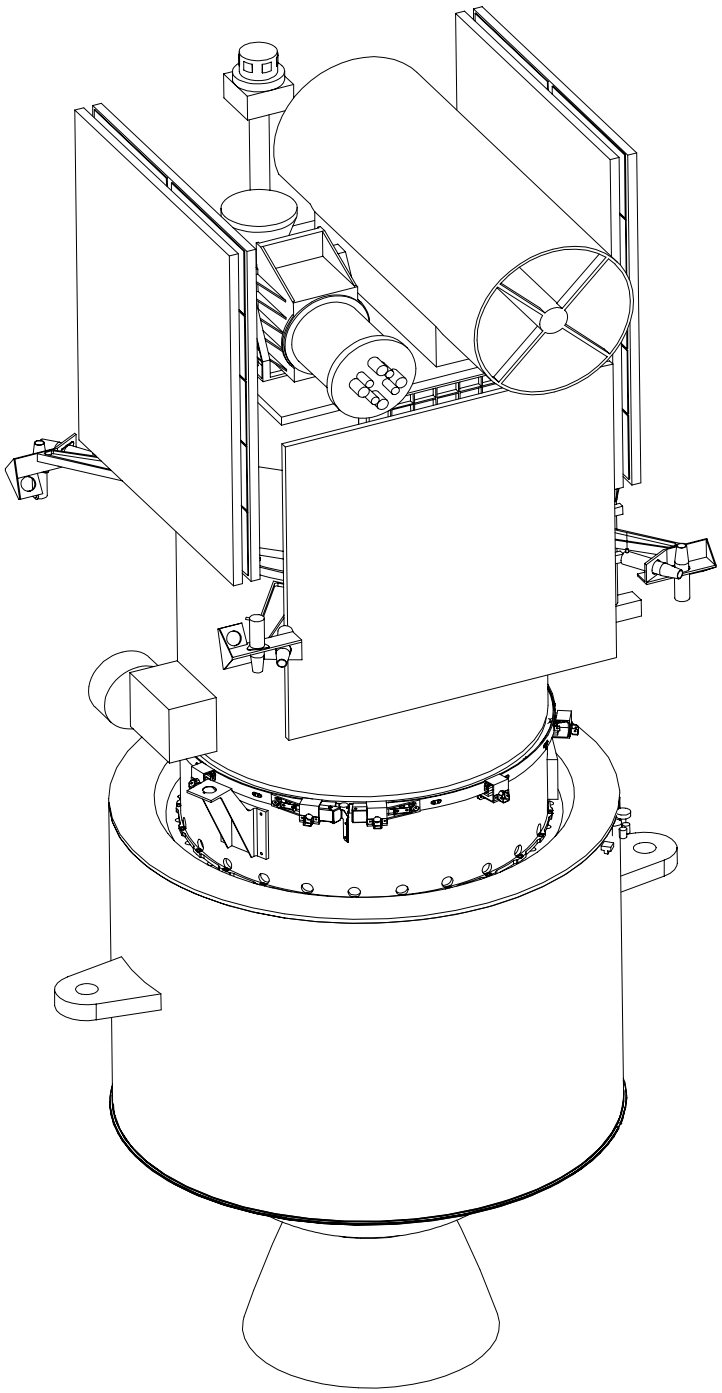
e. Radio Frequency (RF)

f. Thermal

A detailed description of each subsystem can be found in the *Operations Concept Document (OCD) for the Triana Mission*, Triana-OPS-004, NASA/GSFC. This document is located on the Triana Web site.

1322-1

Spacecraft/Payload Drawing



1405-1

Triana uses a transponder that operates on an S-band uplink received frequency of 2090.66 megahertz (MHz). The downlink transmitted frequency will be 2270.4 MHz. The transponder will receive the already-encoded telemetry data from the C&DH subsystem and modulate it for transmission to the ground on one physical channel. It will receive the RF signal transmitted from the ground stations containing commands for the spacecraft, detect them, and send them to the C&DH subsystem for processing.

The Triana command rate is 2 kilobits per second (kbps), and the telemetry rate is selectable. Recorder playbacks will be concurrent with real-time telemetry data.

Both the receiver and the transmitter interface with an omnidirectional antenna system and a separate planar array high-gain antenna (HGA) system.

1420-1

Virtual Channels

Telemetry data will be assembled into dedicated virtual channels by onboard equipment in compliance with the Consultative Committee for Space Data Standards (CCSDS). Triana will use seven of the available eight virtual channels (VC0 through VC7).

a. VC0: Real-time engineering data

   1. Spacecraft housekeeping data
   2. Instrument housekeeping data
   3. Spacecraft attitude data
   4. PlasMag instrument data
   5. NISTAR instrument data

b. VC1: Recorded (playback) engineering data

   1. Recorded spacecraft housekeeping data
   2. Recorded instrument housekeeping data
   3. Recorded spacecraft attitude data

c. VC2: Real-time science data

   EPIC real-time red-green-blue (RGB) instrument data

d. VC3: Recorded science data

   EPIC recorded instrument data

e. VC4: Real-time science data

   EPIC aerosol instrument data

f. VC5: Real-time engineering data

   Table/memory file dumps

g. VC7: CCSDS fill packets

   NOTE: VC7 is not forwarded from the ground stations to the MOC.

1420-2

Data Rates

Telemetry data rates are as follows:

a. Triana will employ selectable data rates up to 267 kbps. Data will be rate 1/2 convolutionally encoded with linear phase modulation (PM) and Reed-Solomon

encoding for all data rates. The high-rate telemetry will include data from all virtual channels.

b. The low-rate telemetry data rate will be 300 bps. Data will be rate 1/2 convolutionally encoded, with biphase-L encoding. Linear PM and Reed-Solomon encoding will also be used. The resulting downlink symbol rate will be 651.583 ksymbols per second. Low-rate telemetry will include VC0.

1420-3

Receiver

Receiver characteristics are as follows:

a. Carrier acquisition threshold into diplexer: -125.0 dBm (decibels referenced to 1 milliwatt of power)

b. Carrier acquisition range: +/-150 kilohertz (kHz) with uplink signal level between -50.0 and -125.0 dBm

c. Carrier tracking range: +/-150 kHz

1420-4

Transmitter

Transmitter characteristics are as follows:

a. Frequency determining source: Either crystal oscillator or derived from uplink (mode dependent)

b. RF power: 5.0 watts minimum

c. Transmitter modulation bandwidth: 5.0 MHz maximum

1420-5

Antennas

Antenna characteristics are as follows:

a. Number, type: One omnidirectional system with two hemispherical coverage antennas (helical elements) and one planar array HGA

b. Full beamwidth: Greater than 90-percent spherical coverage for the omnidirectional system, and 7 degrees for HGA

c. Polarization: Left Hand Circular Polarization (LHCP) for all antennas

d. System minimum gain uplink: 24.0 decibels isotropic (dBi) via HGA

e. System minimum gain downlink: 25.0 dBi via HGA

f. System passive loss uplink: 10.0 decibels (dB) via HGA

g. System passive loss downlink: 2.0 dB via HGA

1420-6

Telemetry Coding

Telemetry coding characteristics are as follows:

1. Code rate: 1/2 bit per symbol
2. Constraint length: 7 bits
3. Connection vectors: G1 = 1111001, G2 = 1011011
4. Phase relationship: G1 is associated with first symbol
5. Symbol inversion: On output path of G2

1430-1

Composite command information will be transmitted on the uplink carrier as nonreturn level zero (NRZ-L) data, biphase shift keying (BPSK)-modulated synchronously on a 16-kHz subcarrier. The spacecraft receiver will demodulate the carrier to produce the baseband command subcarrier signal. The receiver will detect the command data and provide the detected data, bit timing, and lock indication signals to the command decoder system.

All command data received from the ground, via the RF subsystem, are handled by the computational hub (CH). The CH hardware processes the CCSDS Command Link Transmission Unit (CLTU) and code-block error-detection layers according to Command Operating Procedure (COP-1) protocols. Valid code blocks are assembled into telecommand transfer frames. Telecommand packets are extracted from the telecommand transfer frames. The CH will perform a validity check of the application identifier in each packet and will distribute command packets to the appropriate subsystem.

1710-1

The major mission events for the Triana launch can be found in the *PIP for Triana*, NASA/JSC. This document is available online at the Triana Web site.

1715-1

Spacecraft/Payload Major Mission Events

Launch Countdown

a. Support launch site activities

b. Establish spacecraft and ground station configuration

c. Final spacecraft checkout

Launch and Early Orbit

a. Launch

b. Ascent

Deployment

a. Star-48 booster ignition

b. Spacecraft/booster separation

Cruise

a. MCC-1 at L+4 hours to L+18 hours

b. Science off-Earth-pointing calibration slews

On-Orbit Insertion

a. MCC-2 at L+60 days

b. MCC-3 at L+120 days

Normal Operations

a. Routine spacecraft operations

b. Normal instrument operations

c. Full science data

1720-1

Launch vehicle requirements can be found in the *PIP for Triana*, NASA/JSC. This document is available online at the Triana Web site.

1725-1

Spacecraft/Payload Orbital Parameters

Triana will be inserted into a Lissajous halo orbit 2 to 15 degrees about the L1 point.

2000-1

Network Support

Triana telemetry, command, and tracking support functions shall be provided by a commercial ground station network supplemented by NASA assets. Space Network (SN) support is not required for the Triana mission.

Requirement will be met.

2000-1.1

General Ground Support Requirements

Triana telemetry, command, and radiometric ground support will be through a commercial ground network (USN) supplemented by the DSN. The Triana spacecraft will be supported 24 hours per day, 7 days per week. The ground stations will be used for command load uplink, recorder dump, tracking, and health and status verification.

Requirement will be met.

2000-1.2

Deep Space Network Support

The DSN shall be required to support Triana from spacecraft deployment from STS, through cruise and orbit insertion phases. In addition, the DSN will provide backup operations to the USN support during normal on-orbit operations.

DSN Response: Accepted with qualification, as follows:

The DSN neither allocates nor commits its antenna resources. For the 34/70 meter sub-net, these functions are performed by a committee of all Flight Project Users, the Joint User Resource Allocation Planning (JURAP) Committee, which generally is quite successful in negotiating antenna allocations that are acceptable to all parties. Criteria relevant to these negotiations include science content, spacecraft navigation, spacecraft health and safety, and engineering data. For the 26-meter sub-net, the DSN acts as a scheduling agent to assist all of the Flight Project Users in developing a conflict-free schedule.

The Triana coverage requirements have been analyzed in terms of relative priority and daily intensity (i.e., hours/day) and in conjunction with other Flight Project Users of the DSN in CY2001 through CY2006. When the DSN estimates that there is a very high likelihood of being able to meet a particular coverage requirement, the response "accepted" is used. When the ability to meet a particular coverage requirement is less certain, the response "partially accepted" is used, and it is accompanied by further discussion of the DSN ability to meet that requirement.

2000-1.3

Spacecraft Identifier (SCID)

The Triana global and NISN SCID is 116 (octal).

Requirement will be met.

2000-1.4

Support Identification Code

The Triana support identification code is 5512 (decimal). The Triana source/destination code is 6E (hexadecimal).

Requirement will be met.

2000-2

Data Recovery

A minimum of 98 percent of all data collected by the spacecraft shall be recovered over the life of the mission from the USN. The DSN requirement for data collection is a minimum of 95 percent. The goal is to recover 100 percent of all data collected by the spacecraft.

Requirement will be met.

2000-3

Data Volume

Below is the maximum data volume for Triana per day during normal operations:

a. Compressed science data: 1.344 gigabytes

b. Housekeeping: 173 megabytes

c. Software patches, tables, and growth: 3 megabytes

d. Total: 1.52 gigabytes

Requirement will be met.

2005-1

Link Frequency	Item No.	Line Mode	Modulation/ Encoding Scheme	Data Rate	Data Type	Mod. Index		Purpose and Remarks
						CMD	TLM	
Uplink 2090.66 MHz	1	Command	PCM NRZ-L PSK/PM	2.0 kbps	Command	1.0 rad		Normal modes (16 kHz subcarrier)*
Downlink 2270.4 MHz	2	Low-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	**Encoded: 651.583 symbols/sec Decoded: 300 bps	Real-time telemetry		1.2 rad	VC0 (real-time data) VC1 (recorded engineering data) VC5 (table dumps)
	3	Low-rate telemetry	PCM NRZ-L Bi-phase (No R-S encoding or ½ convolutionally encoding)	Encoded: 32.0 ksymbols/sec Decoded: 16.0 kbps	Real-time telemetry		1.2 rad	Same as #2 above
	4	Low-rate telemetry	PCM NRZ-L Bi-phase (No R-S encoding or ½ convolutionally encoding)	Encoded: 64.0 ksymbols/sec Decoded: 32.0 kbps	Real-time telemetry		1.2 rad	Same as #2 above
	5	High-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	Encoded: 149.864 ksymbols/sec Decoded: 69.0 kbps	Real-time telemetry and solid-state recorder dump		1.2 rad	VC0 (real-time data) VC1 (recorded engineering data) VC2 (EPIC RGB data) VC3 (EPIC data) VC4 (EPIC aerosol data) VC5 (table dumps)
	6	High-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	Encoded: 188.959 ksymbols/sec Decoded: 87.0 kbps	Same as #5 above		1.2 rad	Same as #5 above
	7	High-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	Encoded: 241.086 ksymbols/sec Decoded: 111.0 kbps	Same as #5 above		1.2 rad	Same as #5 above

Link Frequency	Item No.	Line Mode	Modulation/ Encoding Scheme	Data Rate	Data Type	Mod. Index		Purpose and Remarks
						CMD	TLM	
	8	High-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	Encoded: 299.728 ksymbols/sec Decoded: 138.0 kbps	Same as #5 above		1.2 rad	Same as #5 above
	9	High-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	Encoded: 377.918 ksymbols/sec Decoded: 174.0 kbps	Same as #5 above		1.2 rad	Same as #5 above
	10	High-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	Encoded: 482.172 ksymbols/sec Decoded: 222.0 kbps	Same as #5 above		1.2 rad	Same as #5 above
	11	High-rate telemetry	PCM NRZ-L Reed-Solomon ½ convolutionally encoded	Encoded: 579.909 ksymbols/sec Decoded: 267.0 kbps	Same as #5 above		1.2 rad	Same as #5 above

*The subcarrier is sine wave.
**Encoding is calculated as decoded data rate x RS(240/221) x rate ½ convolutional encoding (2)

Frequency Utilization Table

Requirement will be met.

2020-1

Summary

Telemetry formats (transfer frame formats and packet formats) are fully described in the CCSDS standard and the mission-specific Telemetry and Command Handbook.

Requirement will be met.

2020-1.1

Encoding

The downlink characteristics for Triana are presented in the Frequency Utilization Table in Requirement 2005-1.

Requirement will be met.

2020-1.2

Modulation

The Triana transponder shall phase-modulate the data signal directly on the carrier. The modulation index shall be maintained between 1.0 and 1.2 radians with 1.2 as the nominal value. The modulation index shall never exceed 1.5 radians.

Requirement will be met.

2020-1.3

Reed-Solomon Coding

Reed-Solomon coding is used for all Triana telemetry rates except the Shuttle captive carry rates of 32 kbps and 64 kbps.

Requirement will be met.

2020-1.4

Transfer Layer

The transfer layer provides a reliable error-controlled transfer of data through the noisy channel. All the data structures of the transfer layer shall be formatted per CCSDS telemetry data standards.

The transfer layer service is provided with CCSDS “Transfer Frames.” This layer’s data structures (Figure 2020-1) include the frame synchronization mark, the transfer frame, and the Reed-Solomon encoding field. The lengths are as follows: the frame synchronization mark is 32 bits (4 bytes), the frame length is 8,800 bits (1,100 bytes), and the Reed-Solomon encoding field is 1280 bits (160 bytes). The total length is 10,112 bits (1,264 bytes).

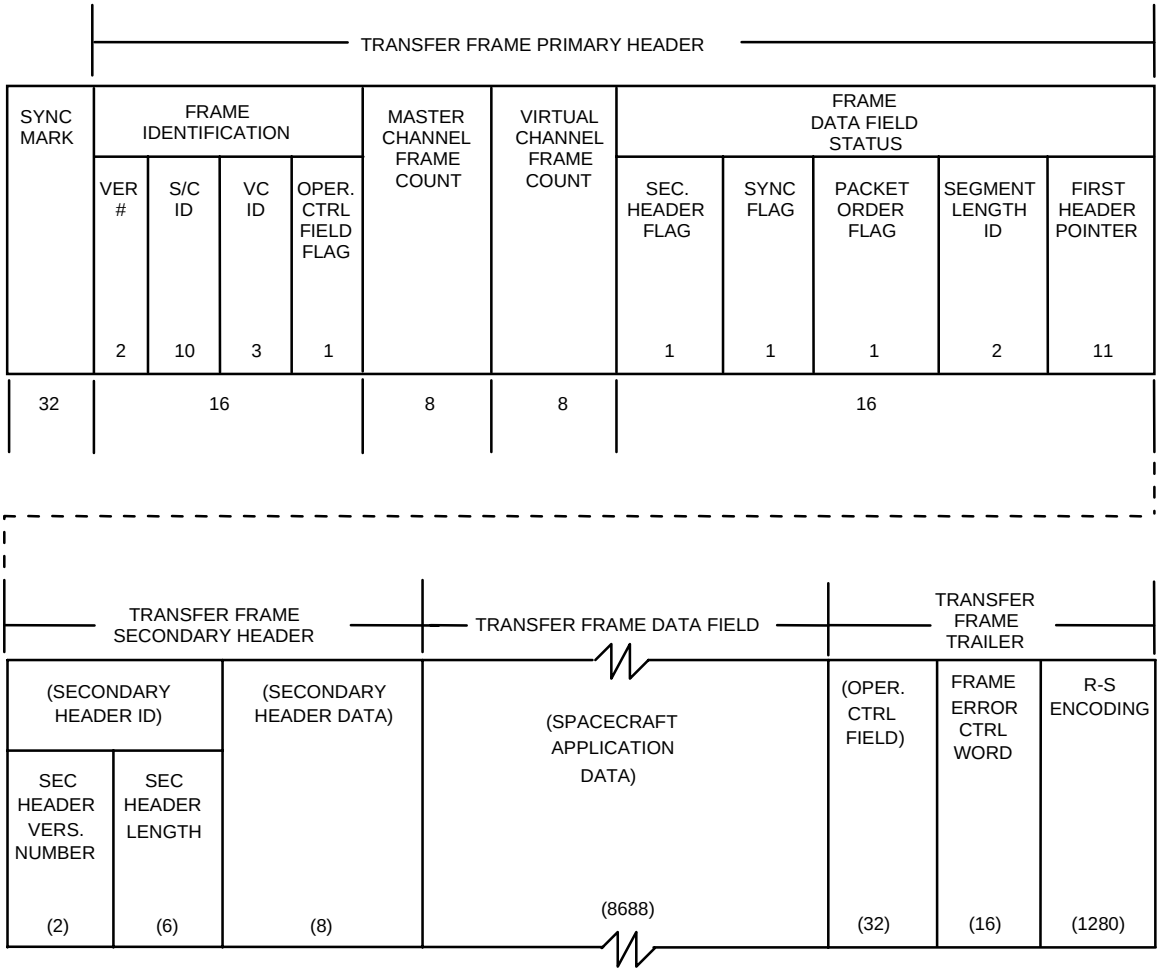


Figure 2020-1: Telemetry Transfer Frame

Requirement will be met.

2020-1.5

Bit Ordering

The CCSDS numbering convention for bit ordering shall be used. The first bit in a data field is defined to be bit 0. For a data field *x* bits in length, bit 0 shall specify the most significant bit (2*x*-1) of that data field, while bit *x*-1 shall specify the least significant bit (20).

Requirement will be met.

2020-1.6

Fill Frames

All fill frame data fields shall contain data consisting of a 256-byte, nonrepeating base-16 pattern (00, 01, 02 . . . FF).

Requirement will be met.

2020-2

Telemetry Data

The CCSDS Version 1 telemetry source packet (Figure 2020-2) shall be used within the transfer frame data field for all real-time (VC0) and recorded spacecraft engineering data (VC1). All data in these two VCs shall be transferred using packets. The minimum packet length in a transfer frame shall be 14 bytes. The maximum length of the telemetry source packet shall be 29,600 bits (3,700 bytes).

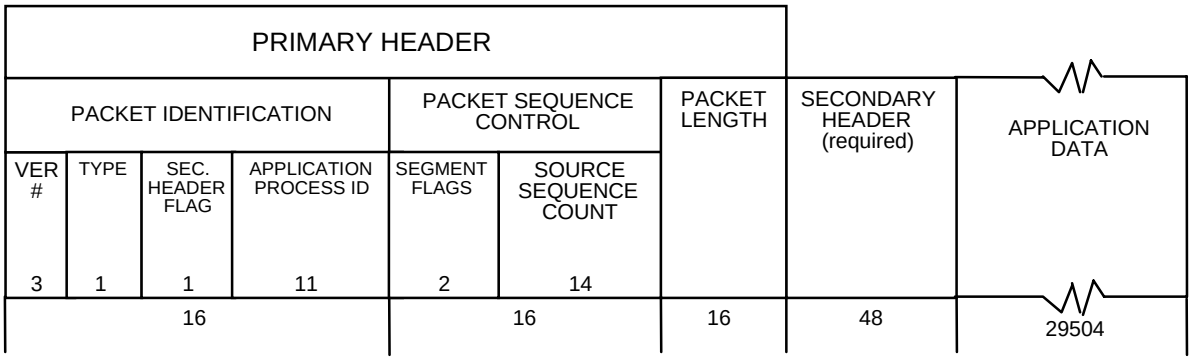


Figure 2020-2: VC0 Telemetry Packet

Triana telemetry data that contain real-time images (VC2 and VC4) and recorded images (VC3) follow the CCSDS transfer frame format described above but do not use the CCSDS packet telemetry format. The format of these data utilizes a Triana-specific format. This format consists of an image information header followed by compressed image data. These data are divided into multiple transfer frames. The first transfer frame of a new image contains the header. The image format will be documented in the *Triana Telemetry and Command (T&C) Handbook,* Volume 1.

Requirement will be met.

2030-1

Command Components

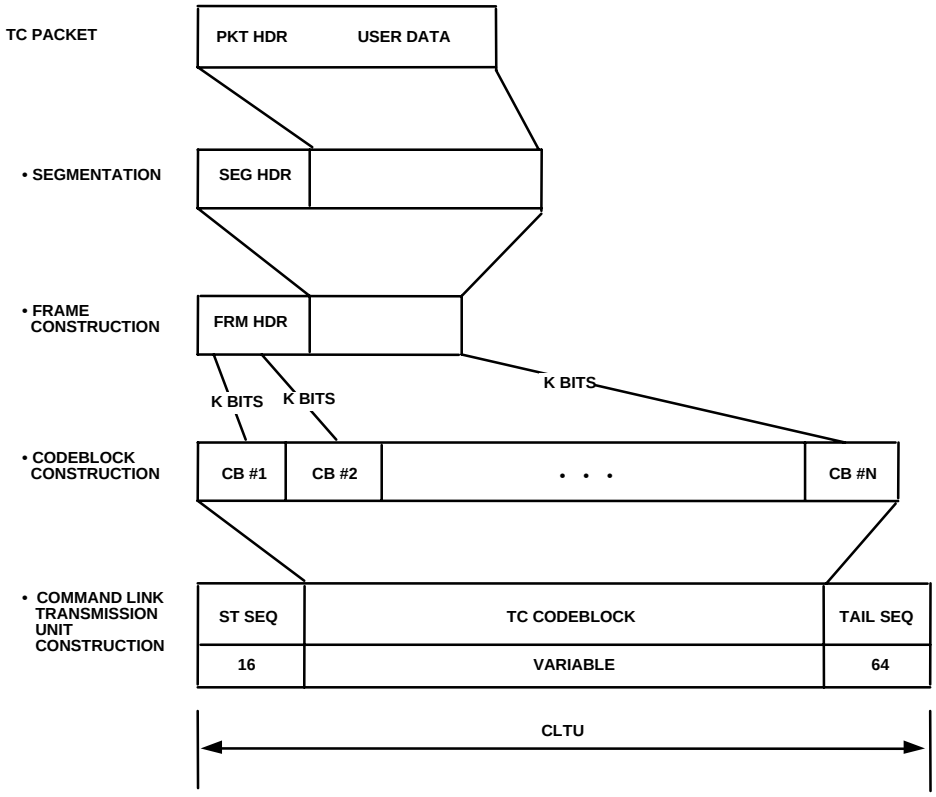
Code blocks are formed by taking the user data (which may consist of multiple telecommand transfer frames) and breaking the data up into 56-bit pieces and adding a parity byte (which consists of 7 bits of parity and 1 spare bit) to each piece. The CLTU consists of a start sequence, code blocks, and a tail sequence.

Requirement will be met.

2030-2

Command Word Structure

The Triana command word structure will use the CLTU data structure (Figure 2030-1).



NOTE: THE DATA FIELD OF EACH CLTU CONTAINS THE ENCODED REPRESENTATION OF ONE OR MORE TRANSFER FRAMES

Figure 2030-1: CLTU Generation

Preamble: At least 132 bits of alternating “ones” and “zeros,” starting with either a one or a zero.

Barker Code: Also referred to as the CLTU start sequence, is a 16-bit synchronization pattern. The start sequence shall start with bit 0, end with bit 15, and is as follows:

1110101110010000 (EB90 hexadecimal)

Postamble: Also referred to as the tail sequence, is a pattern of alternating ones and zeros, beginning with a zero and ending with a one.

There are two data structures used in the transfer layer, transfer frames, and command link control words (CLCWs).

Requirement will be met.

2030-2.1

Telecommand Transfer Frame

The transfer frame is the data structure that is uplinked to the spacecraft. The transfer frame comprises two major fields: Frame Header and Frame Data Field (Figure 2030-2). Triana will not support frame error control.

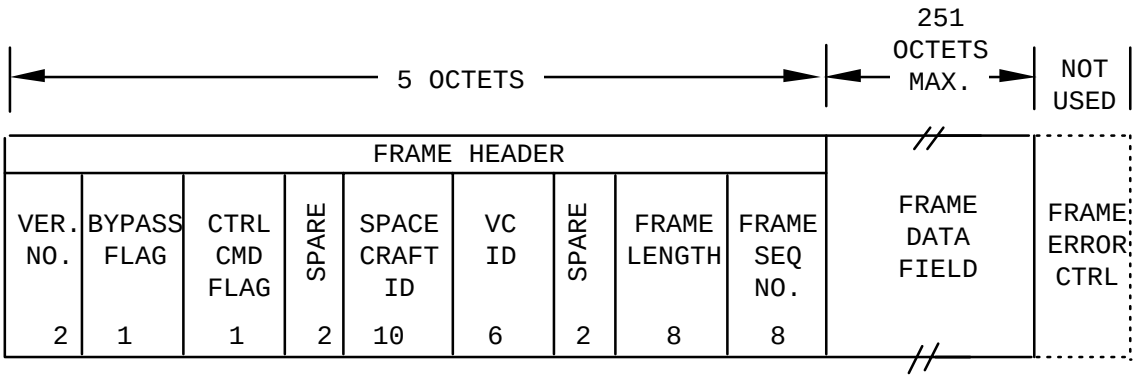


Figure 2030-2: Telecommand Transfer Frame

Requirement will be met.

2030-2.1.1

Segmentation Layer

The segmentation layer is a method to allow commands longer than one transfer frame to be transmitted. The segmentation layer (Figure 2030-3) is included to preserve commonality with SMEX spacecraft and maintain future flexibility.

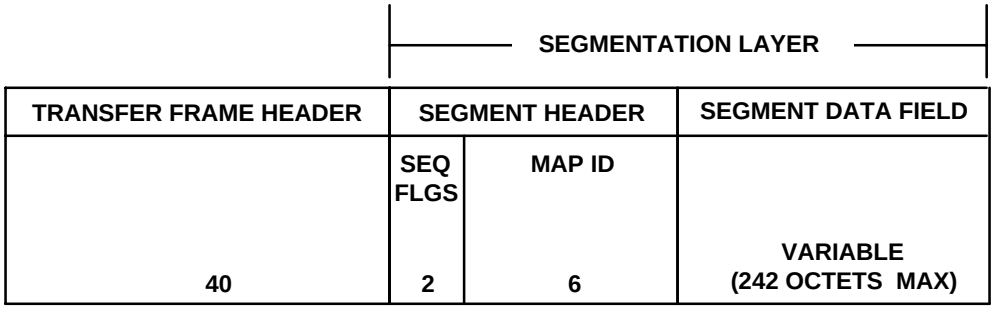


Figure 2030-3: Telecommand Segment

Requirement will be met.

2030-2.1.2

Packetization Layer

The telecommand packet (Figure 2030-4) is the only data structure of the packetization layer. Triana spacecraft design limits the length of telecommand packets to 242 octets to prevent a single transmission from monopolizing the command link.

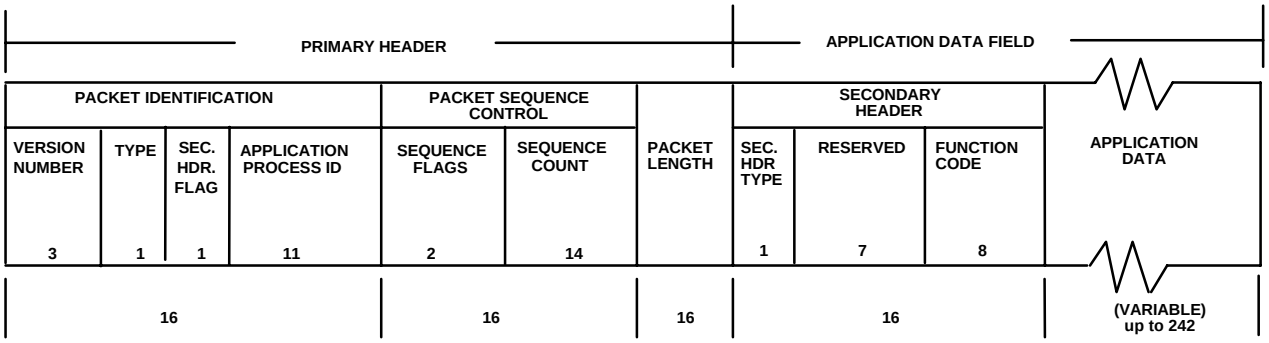


Figure 2030-4: Telecommand Packet

Requirement will be met.

2030-2.2

Telecommand Control Command

A control command consists of only a control specifier (Triana does not use chained control qualifiers). Telecommand control commands (Figure 2030-5) are used to specify to the spacecraft the governing Frame Acceptance Reporting Mechanism (FARM) parameters.

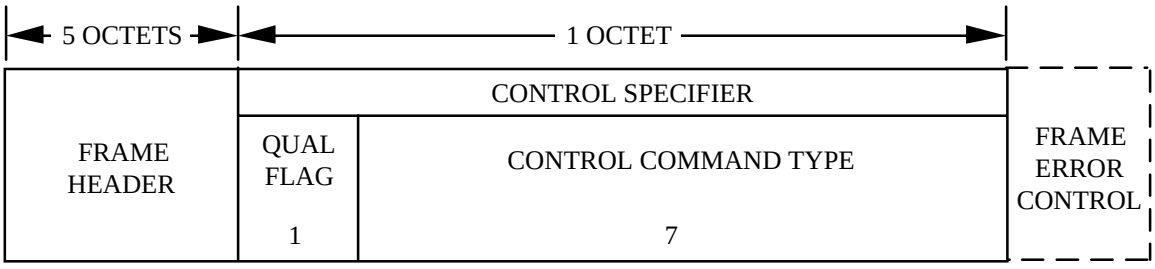


Figure 2030-5: Telecommand Control Command

Requirement will be met.

2030-2.3

Command Link Control Word

The CLCW is downlinked by the spacecraft in every transfer frame in the telemetry link. The CLCW for VC0 (Figure 2030-6) is used to provide an independent closed-loop verification of command receipt on the command link. The CLCW for other virtual channels corresponds with the virtual channel number, contains the static value, and is not used for command verification.

CTRL WORD TYPE	CLCW VER.	STATUS FIELD	COP	VC ID	SPARE	FLAGS					FARM B COUNT	REPORT TYPE	REPORT VALUE
						NO RF	NO LOCK	LOCKOUT	WAIT	RETRANSMIT			
1	2	3	2	6	2	1	1	1	1	1	2	1	8

Figure 2030-6: Command Link Control Word

Requirement will be met.

2200-1

Deep Space Network Requirements

The DSN shall be required to support all phases of the Triana mission. It shall support launch and early orbit (L&EO), spacecraft deployment, cruise to the L1 point, and orbit insertion. The DSN has a 2-hour callup for emergency support and a best effort basis of scheduling contingencies.

Proficiency passes shall be supported on a twice-a-month basis on any DSN-supporting antenna that can be scheduled on a best effort, schedule-available basis.

DSN Response: Accepted

2200-2

Telemetry Bit Error Requirements

The data bit error rate for downlink shall be better than 10E-5, under strong signal conditions (at least 3 dB signal margin).

DSN Response: Accepted

2200-3

Launch and Early Orbit, Deployment, and Cruise Phase Support

During the first 4 months of the mission, Triana ground station support needs will be greater. On the first day of the mission, continuous DSN support shall be required for the first 24 hours. Following this period, DSN support shall be one ground station contact per month of up to 8 hours' duration for each. During this period, the DSN shall complete the postpass transfer of all nonreal-time telemetry (VC3 data) to the MOC within 60 minutes after the loss of signal (LOS) of the pass in which the data was received.

DSN Response: Accepted

2200-4

On-Orbit Support

Once the Triana spacecraft is in its Lissajous orbit about the L1 point, DSN shall support four station-keeping maneuvers per year. Each support shall last approximately 2 hours. Proficiency passes shall be approximately 1.5 hours, including pre- and post-calibration activities. The MOT will schedule additional support from the DSN as needed for spacecraft emergencies.

DSN Response: Accepted

2200-5

Spacecraft Clock Correction

The DSN will not support spacecraft clock correction activities.

DSN Response: Accepted

2200-6

Scheduling

The DSN shall provide a scheduling interface capability with the MOT for scheduling routine recurring support, based on written instructions provided by the project. Additional scheduling requirements are as follows:

a. Provide a single point of contact for scheduling all ground system elements for mission support and premission testing

b. Provide scheduling support 24 hours per day, 7 days per week

c. Respond to a request for critical/contingency support within 90 minutes

d. Provide schedule reports to all applicable ground system elements

DSN Response: Accepted

2210-1

The DSN shall provide coherent Doppler data, tone ranging from the 26-meter sub-net, sequential ranging from the 34-meter sub-net, and angles to the Multi-Mission Flight Dynamics (MMFD). The formats will be Universal Tracking Data Format (UTDF) for the 26-meter tracking data and TRK 2-15a format for the 34-meter tracking data. Transmission will be via Internet Protocol (IP)-encapsulated NASA Communications (Nascom) 4800 bit-block protocol. Doppler data accuracy shall be better than 8 millimeters (mm) per second (3 sigma), and tone ranging data accuracy (bias) shall be better than 100 meters (3 sigma).

DSN Response: Accepted

2220-1

Detailed Downlink Requirements – DSN

The subsequent requirements contain the detailed downlink requirements for the DSN.

DSN Response: Accepted

2220-1.1

Telemetry Interface

The DSN shall interface to a standard Transmission Control Protocol (TCP)/IP interface to transmit CCSDS telemetry data. The telemetry interface shall conform to the Standard Formatted Data Unit (SFDU) format.

DSN Response: Accepted; details to be provided in JPL Document 820-13, TLM-3-33—DSN Telemetry Interface with the Triana Project.

2220-1.2

Quality Statistics

The DSN shall provide composite and transfer frame capture and quality statistics in near-real time (via monitor blocks and voice) for downlink. Monitor block 5-16 will be used for both 26- and 34-meter supports. Ground station quality statistics will be compared to spacecraft and MOC statistics by the MOT personnel to determine whether re-dump or postpass playback from the ground station is necessary and as a fault-isolation tool. At a minimum, the total of good-quality telemetry transfer frames received from the spacecraft for each virtual channel is required.

DSN Response: Accepted with qualification—The DSN will provide monitor block 5-16 from its 26-meter sub-net. However, the 34-meter sub-net will transition from monitor block 5-16 to a new and equivalent monitor data capability, no earlier than mid-2000; details of the transition schedule, including parameters, format, and delivery scheme to be further discussed and negotiated between the Triana Project and JPL Telecommunications Management and Operations Directorate (TMOD).

2220-1.3

Playbacks

The DSN shall provide playback of stored data from the Central Data Recording (CDR) Facility to the MOC via File Transfer Protocol (FTP), as required.

DSN Response: Accepted

2220-1.4

Telemetry Rates

The DSN shall support the data rates identified in the Frequency Utilization Table in Requirement 2005-1.

DSN Response: Accepted

2220-1.5

Recorded/Real-Time Data

The DSN shall provide the capability to support a composite downlink of recorded and real-time data. Data from all virtual channels will be downlinked.

DSN Response: Accepted

2220-1.6

Strip and Ship Capability

The DSN shall provide the capability to strip and ship selected virtual channels. VCs 0, 1, 2, 4, and 5 are shipped in real-time. VC3 is shipped FTP postpass via the CDR. Contents of the virtual channels are specified in Section 1420-1. Each virtual channel will be stored in a separate file for replay in case data from a specific virtual channel is required by the MOC.

DSN Response: Accepted

2220-1.7

Normal Operations Support

The DSN shall provide real-time (VC0) and recorded (VC1) housekeeping telemetry data, EPIC real-time image data (VC2 and VC4), and table/memory file dumps (VC5) to the MOC in real time at a maximum data rate of 267 kbps. The DSN shall strip and store nonreal-time image data (VC3) and ship from the CDR (via FTP) to the MOC within 24 hours of LOS. All fill transfer frames (VC7) are discarded by the DSN and will not be forwarded to the MOC.

DSN Response: Accepted

2220-1.8

Data Storage

The DSN shall store CDR data recordings for 14 days unless otherwise requested.

DSN Response: Accepted

2220-1.9

Voice Links

The DSN shall support a voice link(s) to the MOC.

DSN Response: Accepted

2220-2

Downlink Parameters – DSN and Spacecraft

Unit/Function	Setting
a. Spacecraft total transmitter power	37 dBm
b. Spacecraft passive losses	2 dB
c. Spacecraft antenna gain - Planar array - Omnidirectional	 25.5 dBi 0 dBi
d. Spacecraft Effective Isotropic Radiated Power (EIRP)	60.5 dBm
e. Free-space dispersion loss	-223.7 dB (at maximum slant range of 1605810 km)
f. DSN ground station system noise density (26-meter antenna)	-206.0 dBm/Hz at 5-degree elevation (-208.0 dbw/Hz at 90-degree elevation)
g. Telemetry data channel [pulse-code modulated (PCM)/BiØ-L/PM]/total power	-1.2 dB
h. Ranging/total power	-21.5 dB
i. Telemetry modulation index	1.2 radians (rad)
j. Tone ranging (PM) modulation index	0.5 rad up; 0.2 rad down

DSN Response: Accepted

2230-1

Detailed Uplink Requirements – DSN

The subsequent requirements are the detailed uplink requirements for the DSN.

2230-1.1

Commands

The MOT shall transmit the commands in real-time throughput mode. The commands shall be an IP-encapsulated Nascom 4800-bit-block format.

DSN Response: Accepted

2230-1.2

Command Rate

The DSN shall provide support for commanding at a bit rate of 2 kbps, PCM, NRZ-L, phase shift keying (PSK)/PM modulation.

DSN Response: Accepted

2230-2

Uplink Parameters – DSN and Spacecraft

Unit/Function	Setting
a. DSN ground stations (26-meter antenna) EIRP	84.0 dbW [2-kilowatt (kW) transmitter power] 73.3 dbW (200-watt transmitter power)
b. Free-space dispersion loss	-223.0 dB (at maximum slant range of 1605810 km)
c. Atmospheric loss	-0.4 dB at 5-degree elevation (0.0 dB at 90-degree elevation)
d. Spacecraft antenna gain	+24.0 dBi minimum (directional antenna)
e. Spacecraft passive losses	10 dB
f. Spacecraft system noise density	-168.0 dBm/Hz
g. Uplink carrier phase-lock loop bandwidth	800 Hz
h. Command channel (PCM/PSK/PM)/total power	-4.1 dB
i. Ranging/total power	-9.9 dB
j. Command modulation index	1.0 rad
k. Tone ranging modulation index	0.5 rad up, 0.2 rad down

DSN Response: Accepted

2230-3

Miscellaneous Command Information – DSN

The subsequent requirements contain miscellaneous command requirements for the DSN.

NOTE: Refer to Figure 2030-1: CLTU Generation (Requirement 2030-3) for the command block diagram.

DSN Response: Accepted

2230-3.1

Subcarrier

The subcarrier is a 16-kHz PSK sine wave.

NOTE: The idle pattern shall be transmitted by the DSN during the entire pass.

DSN Response: Accepted

2230-3.2

Preamble

The preamble, also called the acquisition sequence, is at least 132 bits long and consists of alternating “1s” and “0s,” starting with either a 1 or 0. The preamble shall be provided as part of the commands supplied by the MOT.

DSN Response: Accepted

2230-3.3

Sync word

The start sequence shall start with bit 0, end with bit 15, and is as follows:

1110101110010000 (EB90 hexadecimal).

The sync word shall be provided as part of the commands supplied by the MOT.

DSN Response: Accepted

2230-3.4

Postamble

The postamble, also called the tail sequence, is 64 bits long and consists of alternating “1s” and “0s,” starting with a 0 and ending with a 1. The postamble shall be provided as part of the commands supplied by the MOT.

DSN Response: Accepted

2400-1

Nominal Spacecraft Support

The Wallops Flight Facility (WFF) shall not provide support to the Triana mission.

Requirement will be met.

2500-1

Nominal Spacecraft Support

The USN shall provide telemetry, command, and radiometric support for all phases of the Triana mission.

Requirement will be met.

2500-2

Telemetry Bit Error Requirements

The data bit error rate for downlink is 10E-5.

Requirement will be met.

2500-3

Launch and Early Orbit Support

During L&EO, deployment, cruise, and orbit insertion operations (3 to 6 months after launch), Triana ground station support needs will be the most critical. During this period, the USN shall forward all real-time data in VC0, VC1, VC2, VC4, and VC5. USN remote ground stations (RGS) will complete the postpass transfer of all nonreal-time data in VC3 to the MOC within 60 minutes after the LOS of the pass in which the data was received.

Requirement will be met.

2500-4

Contingency Support

The MOT will schedule additional support from other NASA resources as needed.

Requirement will be met.

2500-5

Spacecraft Clock Correction

The spacecraft clock must be maintained to within 1 second of Universal Time Coordinated (UTC) for science processing. To support this requirement, the USN RGS shall apply a ground receipt timetag to all transfer frames as part of the SMEX header. The timestamp shall have an accuracy of 100 milliseconds (ms) and a resolution of 10.0 ms.

Requirement will be met.

2500-6

Scheduling

The USN shall provide a generic scheduling capability for scheduling routine recurring support, based on written instructions provided by the project. Additional scheduling requirements are as follows:

a. Provide a single point of contact for scheduling all USN ground system elements for mission support and premission testing

b. Provide scheduling support 24 hours per day, 7 days per week

c. Respond to a request for critical/contingency support within 60 minutes

d. Provide schedule reports to all applicable ground system elements

Requirement will be met.

2510-1

The USN shall provide coherent Doppler data, tone ranging, and angles. The tracking data format is UTDF and is transmitted via FTP. Tracking accuracy is 8 mm per second, and range accuracy is 100 meters. During L&EO, tracking data will be provided within 15 minutes.

Requirement will be met.

2520-1

Detailed Downlink Requirements – USN

The subsequent requirements contain the detailed downlink requirements for the USN.

Requirement will be met.

2520-1.1

Telemetry Interface

The USN shall interface to a standard TCP/IP interface to transmit CCSDS telemetry data. The telemetry interface shall conform to the IP format described in the *Control Center to Universal Space Network (USN) Commercial Ground Network Interface Control Document: Part 1—General Requirements* and *Part 2—Triana Requirements*.

Requirement will be met.

2520-1.2

Quality Statistics

The USN shall provide composite and transfer frame data capture and quality statistics in near-real time (via monitor blocks and voice) for downlink. Ground station quality statistics will be compared to spacecraft and MOC statistics by the MOT personnel, to determine whether re-dump or postpass playback from the ground station is necessary and as a fault isolation tool. At a minimum, the statistics provided will include the following:

a. Total number of good-quality telemetry transfer frames received from the spacecraft for each virtual channel

b. Number of frames by virtual channel with Reed-Solomon decoding errors that were correctable

c. Number of frames by virtual channel with Reed-Solomon decoding errors that were not correctable

Requirement will be met.

2520-1.3

Playbacks

The USN shall provide playback of stored data to the MOC, as required.

Requirement will be met.

2520-1.4

Telemetry Rates

The USN shall support a baseline data rate of 140 kbps with a minimum of 300 bps and a maximum of 250 kbps. These data rates are before encoding. Encoding techniques will be NRZ-L data and 1/2 convolutional encoding for all data rates. Reed-Solomon encoding will be used.

Requirement will be met.

2520-1.5

Recorded/Real-Time Data

The USN shall provide the capability to support a high-rate downlink of recorded and real-time data. Data from all virtual channels will be downlinked.

Requirement will be met.

2520-1.6

Strip and Ship Capability

The USN shall provide the capability to strip and ship selected virtual channels.

Requirement will be met.

2520-1.7

Normal Operations Support

The USN shall provide real-time (VC0) and recorded (VC1) housekeeping, real-time science (VC2 and VC4), and table/memory file dumps (VC5) telemetry data to the MOC in real time. The USN shall strip and store nonreal-time science data (VC3) and transmit postpass (via FTP) to the MOC within 24 hours of LOS.

Requirement will be met.

2520-1.8

Voice Links

The USN shall support a voice link(s) to the MOC.

Requirement will be met.

2520-2

Downlink Parameters – USN

Unit/Function	Setting
a. Spacecraft total transmitter power	37 dBm
b. Spacecraft passive losses	2 dB
c. Spacecraft antenna gain - Planar array - Omnidirectional	 25.5 dBi (0 dBi)
d. EIRP (planar array)	60.4 dBm
e. Free-space dispersion loss	-223.7 dB (at maximum slant range) of 1605810 km)
f. USN ground stations system noise density	-176.6 dBm/Hz at 5-degree elevation (-176.6 dBm/Hz at 90-degree elevation)
g. Telemetry data channel (PCM/BiØ-L/ PM)/total power	-119.2 dBm
h. Ranging/total power	-123.0 dBm*
i. Telemetry modulation index	1.2 rad
j. Tone ranging (PM) modulation index (major + minor tones)	0.5 rad up; 0.2 rad down

*Note: No telemetry while ranging due to ranging tone-bit rate interference.

Requirement will be met.

2530-1

Detailed Uplink Requirements – USN

The subsequent requirements are the detailed uplink requirements for the USN.

2530-1.1

Command Interface

The USN shall interface to a standard IP interface to receive Triana commands for uplink.

Requirement will be met.

2530-1.2

Prepass Commanding

The USN shall provide prepass command verification. Prepass data flows will check the functional command and telemetry paths.

Requirement will be met.

2530-1.3

Command Rate

The USN shall provide support for commanding at a bit rate of 2 kbps. Spacecraft commands provided by the MOC will be uplinked to the spacecraft in real time (throughput mode). Command uplink will be PCM, NRZ-L, PSK/PM modulation, and 2-kbps rate.

Requirement will be met.

2530-2

Uplink Parameters – USN

Unit/Function	Setting
a. USN ground stations (13-meter antenna) EIRP	68.5 dBw (100-watt transmitter power)
b. Free-space dispersion loss	-223.0 dB (at maximum slant range of 1605810 km)
c. Atmospheric loss	-0.4 dB at 5-degree elevation, -0.0 dB at 90-degree elevation
d. Spacecraft antenna gain	-24.0 dBi minimum
e. Spacecraft passive losses	10 dB
f. Spacecraft system noise density	-168.0 dBm/Hz
g. Uplink carrier phase-lock loop bandwidth	64.8 dB/Hz

Unit/Function	Setting
h. Command channel (PCM/PSK/PM)/total power	-114.4 dB for command alone*
i. Ranging/total power	-112.2 dBm*
j. Command modulation index	1.0 rad
k. Tone ranging modulation index	Modulation index is less than or equal to (0.7 + 0.7) rad (major + minor tones)

*Note: No telemetry while ranging due to ranging tone bit rate interference.

Requirement will be met.

3000-1

General

The integration and testing of the Triana spacecraft will verify its readiness for launch and for accomplishing its mission. A full performance test will be conducted before the spacecraft is shipped to the launch site to verify that all systems are working, and to develop a baseline for later tests at the launch site. At the launch site, a post-shipment functional test will be performed to verify the spacecraft status before launch. Triana integration and test activities include the following:

a. Intersystem testing, which considers interfaces, interactions, and compatibility

b. Spacecraft-level environmental testing, which considers structured dynamic and orbital mode tests based on the predicted space environment

The following requirements give an overview of the various tests and training to be performed and the resources required to support them. The MOT is involved to varying degrees in each of these test efforts. The following tests and training are described:

a. Compatibility tests

b. Networks readiness tests

c. Mission readiness testing

d. Operations and systems training

NOTE: The requirements and schedule for testing and training listed in the various sections of the Detailed Mission Requirements (DMR) are preliminary. The controlling documents with respect to Triana prelaunch testing and training will be the *Spacecraft Integration and Test Plan* and the *Mission Readiness Test Plan (MRTP).*

Requirement will be met.

3000-2

Test and Training Overview

See subordinate requirements.

3000-2.1

Compatibility Testing (3100)

a. RF Compatibility Testing (3110). Ensure spacecraft RF compatibility with all the ground sites.

b. Ground System Compatibility Testing (3130). Verify compatibility between spacecraft and all ground system elements that will receive spacecraft data directly from the ground sites.

Requirement will be met.

3000-2.2

Networks Readiness Testing (3200)

Verify mission readiness of all ground station hardware, software, and personnel and the interfaces between the ground sites and GSFC required to support the Triana mission.

Requirement will be met.

3000-2.3

Mission Readiness Testing (3300)

a. Ground Data System Integration and Testing (3310). Conduct internal ground system element tests to verify performance. (Also refer to Section 4440.) Conduct element-to-element tests to verify all interfaces, and conduct ETE tests to verify full system performance prior to operational testing.

b. Project Operations Testing (3320). Conduct rehearsals to simulate various mission scenarios/mission modes. Conduct ETE tests to rehearse operations and verify comprehensive system operational functionality and performance, and to validate operations plans and procedures.

c. Launch Readiness Testing (3330). Conduct RF, data flow, and spacecraft functional tests to ensure spacecraft health after shipment to the launch site and to verify data and voice connectivity for launch operations.

Requirement will be met.

3000-2.4

Operations and Systems Training

Operations and systems training objectives may be fulfilled simultaneously with test activities. Any remaining training objectives may be met through the use of simulations.

Requirement will be met.

3000-3

Mission Test and Training Functional Configuration

A high-level mission test and training functional interface chart is shown in Figure 3000-1. Operations support element (MOC, FDSS, etc.) interfaces are not provided in this chart. The support elements will use the interfaces described in the Ground System Functional Interfaces Diagram in Section 4410.

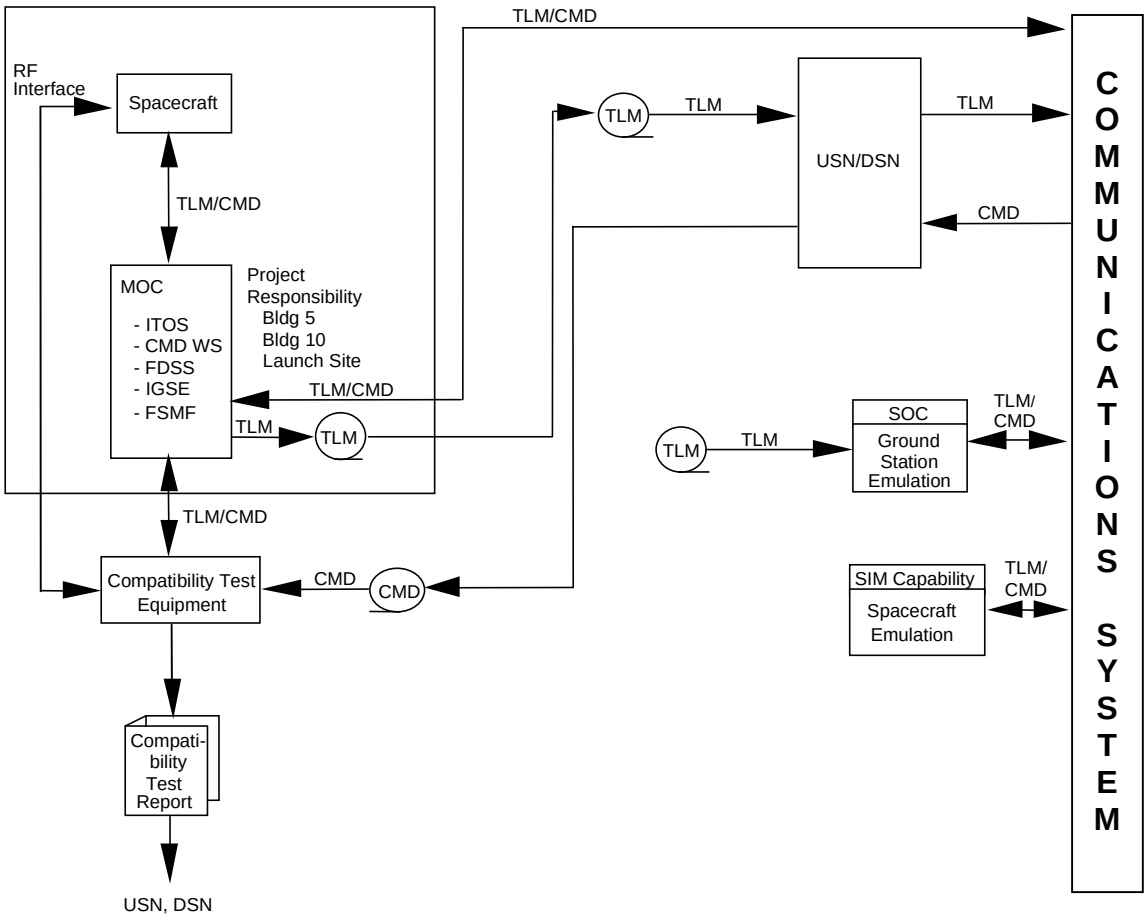


Figure 3000-1: Mission Test and Training Functional Interface

Requirement will be met.

3000-4

Testing and Training Schedule

A preliminary mission test and training schedule chart is shown in Figure 3000-2. The chart represents a preliminary testing schedule that identifies anticipated tests, possible participants, the approximate time tests will occur, data sources [data generator, spacecraft, taped telemetry, SOC, or engineering test unit (ETU)], and some clarifying comments regarding these tests. The schedule is dependent upon prompt release and delivery of MOC hardware and software. MOC hardware and software must be thoroughly tested prior to use in operations testing and training. For the actual testing and training schedules, reference the controlling documents listed in Section 3000-1.

The current ground data system development and testing schedules are available on the Triana Web site at www.triana.gsfc.nasa.gov/home/ using Intranet and then the Project folder.

Test/Training	When	Participants	Data Source	Duration	Comments
Internal testing	L-12 to L-2 months	All elements	Recorded data, internal simulation	N/A	No spacecraft support required.
Integrated testing	L-9 to L-0 months	Ground systems, MRTT	Recorded data, integrated simulation	N/A	USN is prime network; DSN is backup.
ETE testing	L-2 months	Ground systems, MRTT	Tape data	2 x 12 hours	
MOC compatibility	L-8 to L-0 months	I&T, MRTT, NISN, MOC, FDF, MOT, TSOC, ISTP CDHF	Spacecraft	4 x 8 hours maximum	Minimum of four spacecraft test opportunities for MOT at GSFC. This includes mission mode testing (L&EO and normal operations simulations) during S/C thermal vacuum testing.
RF compatibility testing - JPL	L-6 months	JPL, I&T, MRTT, MOC	Spacecraft	N/A	In conjunction with USN compatibility testing performed with the spacecraft.
RF compatibility testing - USN	L-6 months	USN, I&T, MRTT, MOC	Spacecraft	16 hours	Testing performed with the spacecraft.
RF compatibility testing – RF telemetry	L-8 to L-0 months	USN, DSN, MRTT, MOC, NISN, I&T,	Spacecraft/ tape	N/A	Generate tapes or binary files of encoded raw telemetry in all data rates. Tapes/files to be shipped to sites for use in data flow tests.
Launch site testing	L-1 month	KSC, NISN, MOC, I&T, FDF, MRTT, TSOC, ISTP CDHF	Spacecraft/ tape	8 hours	Flow telemetry data from spacecraft through KSC and route to GSFC elements.

Figure 3000-2: Mission Test Schedule

Requirement will be met.

3100-1

General

a. GSFC RF compatibility test personnel, communication services, ground stations, the GSFC SOC or equivalent shall support prelaunch testing and simulations for Triana.

b. Transportable media will be made available from spacecraft integration and testing activities for ground system and interface testing (see Section 3110-1a).

c. Compatibility testing will be performed at GSFC (see Section 3110-1b).

The following types of spacecraft compatibility testing will be performed:

a. RF compatibility testing (Section 3110)

b. Spacecraft-ground data system compatibility testing (Section 3130)

c. Spacecraft-to-MOC compatibility testing

Requirement will be met.

3110-1

RF Compatibility

RF compatibility is required as follows:

a. Command and telemetry tests – Encoded telemetry tapes or binary files will be required as follows:

   Using the spacecraft as the data source, generate transportable media copies or files of the baseband encoded downlink signal, ship the transportable media copies or files to USN and DSN, and perform data flows from ground sites to GSFC. Transportable media copies or files are to be generated during compatibility testing by the GSFC compatibility test group and sent to all of the applicable ground stations.

b. Compatibility testing – Develop an RF testbed to support compatibility testing of the Triana transponder. This testbed is to evaluate anticipated signal strength data, as well as command and telemetry. (See Section 2000 for details.)

   1. To support RF compatibility testing, the project integration and test (I&T) schedule will reflect 16 (2 x 8) hours of spacecraft test time. An RF link to the fiber-optic system in Bldg.7 will be established to facilitate dedicated spacecraft testing and parallel monitoring of the Triana transponder.

   2. Use USN compatibility equipment and, if desired, DSN equipment, and USN, DSN, and GSFC personnel to characterize and validate performance of the integrated spacecraft to ensure compatibility with the ground system for all flight modes and data rates. Provide report of results for use by the Project, USN, and DSN.

Requirement will be met.

3130-1

General

Compatibility tests shall be conducted between the spacecraft and those ground system elements that will receive/process spacecraft data received directly from the ground sites via electronic communication services or storage media. This includes spacecraft data flows from the launch site.

Requirement will be met.

3130-2

MOC Compatibility Testing

MOC compatibility testing will be conducted to verify that the MOC can command the spacecraft, and ensure that the MOC can process spacecraft telemetry data. MOC compatibility will be planned and performed by the MOT under the control of I&T.

NOTE: MOC-to-FDSS compatibility test will be performed during the MOC compatibility tests using spacecraft-generated attitude data. If interfaces and systems are not in place to support functional testing, the spacecraft attitude test data will be recorded and used for compatibility testing later.

Requirement will be met.

3200-1

General

Network readiness testing shall be conducted with all of the ground sites to verify the functional interfaces between GSFC and the sites and to ensure mission readiness of ground station hardware, software, and personnel.

The ground stations, NISN, and MOC shall provide the resources required to perform the tests listed below.

Requirement will be met.

3200-2

Ground System Data Handling Testing

Using telemetry tapes or site-provided data generators, data flows will be performed between Triana ground stations and the MOC:

a. Verify that all telemetry data flows are properly processed and handled by the ground system. Ensure system can accommodate peak data rates.

b. Verify that all command flows are properly processed and handled by the ground system.

c. Verify that status and accounting information provided by the ground stations is correct.

d. Perform testing to verify scheduling system interfaces.

Requirement will be met.

3200-3

USN Time Capture Testing

Time capture testing at USN ground stations is performed as follows:

a. Perform testing to verify USN time capture equipment specification.

b. Support operations testing of time maintenance, using USN time capture equipment, to provide ground-latched time at USN ground stations and simulated spacecraft time latch.

Requirement will be met.

3300-1

General

The Mission Readiness Test Section (MRTS) is responsible for verifying that all ground system requirements are met and the elements are ready to support all Triana mission phases.

Requirement will be met.

3310-1

General

Integrated testing of the Ground Data System (GDS) will be accomplished between L-9 months and the Launch Readiness Review (LRR). The goal of integrated testing will be the verification of all testable GDS requirements, as listed in this DMR. From this document, the Mission Readiness Test Manager (MRTM) will develop the Triana Mission Readiness Test Plan. The readiness plan will define how integrated testing will be accomplished. A series of integrated system tests include, but are not limited to, the following:

a. Telemetry data flow tests

b. Command data flow tests

c. Mission planning and scheduling tests

d. Attitude/orbit data flow and product tests

e. Flight software development and uplink tests

f. Science data flow tests

The Triana Project Office will maintain the project-level GDS schedule to provide a conflict-free integrated testing schedule. The MRTS will formally track all discrepancies.

Prior to the start of integrated testing, GDS elements will perform internal acceptance and initial interface testing. The MRTS will support these tests.

After the conclusion of integrated testing, the MRTS will coordinate ETE testing from both ground and launch site locations.

All GDS elements will be launch capable at environmental testing minus 30 days to support ETE testing.

Requirement will be met.

3310-2

End-to-End Testing

The MRTS will conduct comprehensive data flow tests to verify the end-to-end system functionality for all data flow types. ETE tests of all products through the system (e.g., end-to-end science data flow, engineering data flow, command flow, orbit/attitude data flow, planning/scheduling data flow, and the flight software data flow) will be verified. ETE testing will be performed from the ground sites and the launch site.

Requirement will be met.

3320-1

General

Project operations testing of the ground systems shall occur in conjunction with MRTS verification of the systems' end-to-end functionality. As often as possible, the spacecraft and ETU will be used as the data source. Recorded data from I&T will be used to augment the operations testing to allow repeatability of tests.

Requirement will be met.

3320-2

Mission Mode Testing

Mission mode testing (in coordination with the I&T team) will be performed to test the spacecraft in various mission modes. These tests will validate the spacecraft performance in mission modes, as well as validate the ground systems and operational procedures. Testing will include, but not be limited to, the following:

a. Two normal operations tests, including anomalous conditions

b. One L&EO operations test

Requirement will be met.

3320-3

Simulations

Tape data and the ETU will be used to conduct ongoing simulations to verify MOC and other ground system operational performance and to verify operational procedures.

Requirement will be met.

3330-1

General

RF, data flow, and spacecraft functional tests shall be conducted to ensure spacecraft health after shipment and mate, and to verify data and voice connectivity for launch operations.

Requirement will be met.

3330-2

Launch Site Testing

ETE testing shall be performed from the launch site using both transportable media and spacecraft data sources. Telemetry shall be routed to GSFC. Commanding from the MOC (at GSFC) is required.

Requirement will be met.

3330-3

Launch Site Communication

Pre-test data flows shall be performed from various spacecraft processing facilities to the I&T ground support equipment (GSE), MOC, and other participating facilities. This verifies the mechanism for testing command and telemetry communication support from the launch site facilities to I&T GSE and MOC. The MOC requires telemetry and voice communications with the launch site. Commanding from the MOC to the launch site is required.

Requirement will be met.

3400-1

General

Simulations shall be conducted to verify total system readiness, prepare personnel for actual operations, verify coordination between elements, and test contingencies. Data tapes, ground site data generators, SOC, and the spacecraft and ETU (when available) will serve as data sources. Several normal and L&EO simulations will be performed using actual personnel, voice, facilities, procedures, and systems to be used during the mission. This section discusses requirements for simulators and equipment to support mission readiness testing and training. Functions of the following systems are described in subsequent sections:

a. SOC

b. Data Evaluation Laboratory (DEL)

c. Project ETU

Requirement will be met.

3400-2

Simulations Operations Center

The SOC shall perform as required the following functions:

a. Provide NISN interface and voice.

b. Support data flows at all spacecraft data rates.

c. Provide capability to flow taped spacecraft data across the NISN interface.

d. Provide capability to inject errors into uplink/downlink (transfer frame, packet).

e. Support the network and mission testing and simulation, as requested.

f. Maintain data stream accounting.

g. Receive and ship composite data stream to MOC.

h. Strip selected VCs from composite data stream and ship to MOC.

i. Record simulated dump data and ship at a reduced rate.

j. Support commanding and telemetry interfaces using IP protocols [TCP/IP and (UDP)/IP] as a replacement to the NISN serial interface.

Requirement will be met.

3400-3

Data Evaluation Laboratory

The DEL will generate or duplicate telemetry tapes or other applicable storage media, compatible for use in data flow tests by the ground stations and SOC.

Requirement will be met.

3400-4

Standard Command and Telemetry Requirements

Using a project-provided project database (PDB) or the *Triana T&C Handbook*, the project ETU, if available, shall provide the telemetry and command simulation as described below:

a. The ETU shall be capable of accepting and verifying for format all valid Triana spacecraft commands.

b. The ETU shall perform full CCSDS COP-1 validation and dynamics as implemented for Triana.

c. The ETU will be capable of generating one physical real-time telemetry stream. The telemetry will include valid transfer frame and packet formats with dynamic time, sequence counter, and CLCW values, and correct Reed-Solomon encoding. Packet data will use either a fixed pattern (all 1s, all 0s, alternating 0 and 1) or (project provided) hard-coded realistic data that is repeated periodically in the downlink.

NOTE: For further description of Triana's telemetry and command formats, rates, and specific CCSDS features implemented for the Triana mission, see the *Triana T&C Handbook.*

Requirement will be met.

4000-1

Mission Operations Center

The MOC shall provide all systems and facilities required to support spacecraft integration and test, L&EO, and on-orbit operations. The MOC will send commands; receive, distribute, and archive spacecraft data; provide spacecraft health and safety monitoring functions; and provide offline trending and analysis. MOC capabilities shall include the following:

a. MOC systems

b. Flight software maintenance

c. MOC facilities

d. MOC operations support

Requirement will be met.

4100-1

MOC Systems

The MOC systems shall provide all ground data system interfaces during spacecraft testing, launch site operations, and on-orbit operations. These systems will determine spacecraft performance during tests and simulation. The MOC systems shall consist of a real-time telemetry and command system, a command generation system, and a data trending and analysis system (DTAS). The real-time system will share functionality with the spacecraft I&T GSE, forming an Integrated Test and Operations System (ITOS). The MOC systems capabilities shall include the following:

a. Spacecraft-to-MOC interface

b. MOC-to-spacecraft interface

c. Mission planning and scheduling

d. User interaction

e. Trending analysis

Requirement will be met.

4110-1

Spacecraft-to-MOC Interface

NISN shall provide the interface from both the spacecraft I&T GSE and the operations ground stations to the MOC. This interface will be used to verify end-to-end system requirements, support operations testing, and support spacecraft operations. The MOC will interface with the I&T system during operations testing and the ground stations during spacecraft operations. Spacecraft-to-MOC interface capabilities shall include the following:

a. Telemetry handling

b. Spacecraft health and safety monitoring

c. Autonomous spacecraft pass operations

Requirement will be met.

4111-1

Telemetry Handling Overview

The ITOS shall receive, process, and monitor telemetry data from the Triana spacecraft. All data received by the ITOS will comply with the project-defined data standards as specified in the *Triana T&C Handbook* and the CCSDS Space Data Packetization Standard.

Requirement will be met.

4111-2

Data Capture

The ITOS shall receive/capture, process, and monitor telemetry transfer frame data using IP network protocol from any source. Data capture capabilities shall include providing

a. TCP and UDP transport protocols

b. Telemetry transfer frames receipt

c. Real-time telemetry packet processing

d. Telemetry data source selection

e. Recorded telemetry packet processing

Requirement will be met.

4111-2.1

Real-Time Telemetry Transfer Frame Receipt

The ITOS shall receive spacecraft telemetry transfer frames from only one telemetry source at a time using IP network protocol.

Requirement will be met.

4111-2.2

Real-Time Telemetry Packet Processing

The ITOS shall provide the capability to process real-time telemetry packets (VC0 and VC5) and real-time science telemetry (VC2, VC3, and VC4) at a minimum data rate of 96 kbps.

Requirement will be met.

4111-2.3

Telemetry Data Source Selection

The ITOS shall provide the capability to select a new telemetry data source and reinitialize the status and accounting parameters within 20 seconds of the request. This includes resetting the Current Value Table (CVT) and purging all previously received telemetry data.

Requirement will be met.

4111-2.4

Recorded Telemetry Packet Processing

The ITOS shall provide the capability to process recorded telemetry packets (VC0, VC1, and VC5) and recorded image telemetry (VC2, VC3, and VC4) from the ground station.

Requirement will be met.

4111-3

Data Processing

The ITOS shall distribute, process, and archive spacecraft and ground system generated data. Data processing capabilities shall include providing

a. SMEX header extraction
b. Transfer frame extraction
c. CLCW extraction
d. Source packet extraction
e. Image extraction
f. Data quality-checking and annotation
g. Transfer frame processing statistics
h. Transfer frame statistics reporting
i. Telemetry data archiving
j. Virtual channel data sorting
k. Telemetry history data recording
l. Telemetry history data replay
m. Telemetry history data maintenance
n. Transfer frame and packet dumps

Requirement will be met.

4111-3.1

Transfer Frame Processing

The ITOS shall accept frame-synchronized data via the IP network.

Requirement will be met.

4111-3.1.1

The ITOS shall identify/extract frame sequence error from the SMEX header.

Requirement will be met.

4111-3.1.2

The ITOS shall not flag as bad quality the data extracted from the telemetry transfer frames containing only sequence errors in the VC frame count.

Requirement will be met.

4111-3.1.3

The ITOS shall perform telemetry frame time extraction.

Requirement will be met.

4111-3.2

CLCW Extraction

The ITOS shall support CCSDS COP-1 protocol for commanding.

Requirement will be met.

4111-3.2.1

The ITOS shall validate CLCW data quality. If a transfer frame has an error, the CLCW will not be extracted.

Requirement will be met.

4111-3.2.2

The ITOS shall complete the command frame sequence verification within 1 second of receiving a valid incremented CLCW.

Requirement will be met.

4111-3.3

Source Packet Extraction

The ITOS shall extract CCSDS packet telemetry data from telemetry transfer frame data.

Requirement will be met.

4111-3.3.1

The ITOS shall provide packets to external systems as requested.

Requirement will be met.

4111-3.3.2

The ITOS shall extract raw telemetry parameters from telemetry packets as specified in the *Triana T&C Handbook.*

Requirement will be met.

4111-3.4

Data Quality Checking and Annotation

The ITOS shall extract data quality from the SMEX header and append the information to each source packet.

Requirement will be met.

4111-3.4.1

Transfer Frame Sequence Accounting

The ITOS shall provide transfer frame sequence accounting based on virtual channel assignment. Sequence errors do not necessarily indicate that there is an error in the data.

Requirement will be met.

4111-3.4.2

Transfer Frame Reed-Solomon Decoding Errors

The ITOS shall provide a count of transfer frames that were corrected by the Reed-Solomon decoding function at the ground station.

Requirement will be met.

4111-3.5

Transfer Frame Processing Statistics

The ITOS shall provide transfer frame processing statistics on each virtual channel and on the aggregate. The frame processing statistics will include the total number of frames

for each of the following categories: received, good frames, sequence errors, and Reed-Solomon decoding errors.

Requirement will be met.

4111-3.6

Transfer Frame Statistics Reporting

The ITOS shall provide an event message indicating that a sequence or Reed-Solomon frame decoding correction has occurred. No more than one sequence error or Reed-Solomon correction event message should occur every 5 seconds.

Requirement will be met.

4111-3.7

Telemetry Data Archiving

The ITOS shall provide telemetry data archiving capability that will allow the user to archive selected data to specified files at a rate of at least 250 kbps.

Requirement will be met.

4111-3.8

Virtual Channel Data Sorting

The ITOS shall sort transfer frame data into files for archiving by its virtual channel assignment. The users will select which virtual channels will be archived.

Requirement will be met.

4111-3.9

Telemetry Data Replay

The ITOS shall replay telemetry transfer frames based on user selection ground receipt time, virtual channel identifier (VCID), and/or spacecraft time. The replay rate shall be user selectable with a minimum rate of 100 kbps without any errors.

Requirement will be met.

4111-3.10

Telemetry Data Maintenance

The ITOS shall create and open a new frame archive file or close and delete an existing frame archive file on user request. This capability allows the user to store each recorder dump to a separate file.

Requirement will be met.

4111-3.11

Transfer Frame Dumps

The ITOS shall write hexadecimal dumps of CCSDS transfer frames and packets to a file, display, or printer via a user directive. The ITOS shall allow the user to select the frames to be dumped by specifying the VCID.

Requirement will be met.

4111-3.12

The ITOS shall be able to extract the ground-received frame time from the SMEX telemetry header.

Requirement will be met.

4111-3.13

The ITOS shall be able to perform copy in/out (CPIO) extraction of the VC1, VC2, VC3, VC4, and VC5 files either in real-time or offline processing.

Requirement will be met.

4111-3.14

The ITOS shall be able to perform Reed-Solomon decoding on data received from all DSN sites at a minimum data rate of 256 kbps.

Requirement will be met.

4112-1

Spacecraft Health and Safety Monitoring Overview

The ITOS shall monitor spacecraft engineering and housekeeping data in real time, at a maximum data rate of 80 kbps, to determine the status of the spacecraft and its instruments. The ITOS will assess the spacecraft health and safety and notify the user of anomalies or out-of-limit conditions with suitable displays and alarms.

Requirement will be met.

4112-2

Telemetry Decommutation

The ITOS shall extract data from the source packets, and calibrate and convert individual telemetry parameters as identified in the mission database. Telemetry decommutation capabilities shall include providing

a. Data extraction

b. State conversions

c. Engineering unit (EU) conversions

Requirement will be met.

4112-2.1

Data Extraction

The ITOS shall support the extraction of all data types as specified in the *Triana T&C Handbook*. The ITOS shall store the latest extracted raw values of telemetry mnemonics in the system and make these raw values available to all GDS elements.

Requirement will be met.

4112-2.2

State Conversions

The ITOS shall provide discrete state conversions as identified in the mission database. Multibit discretes will be supported (up to 32 bits, 16 states). Bits may be concatenated from noncontiguous location to form a single telemetry parameter. The ITOS shall display states in different colors.

Requirement will be met.

4112-2.3

Engineering Unit Conversions

The ITOS shall provide conversion from downlinked raw values to EUs, as identified in the mission database and *Triana T&C Handbook*. The ITOS shall provide the capability to temporarily change EU conversions.

Requirement will be met.

4112-3

Telemetry Displays

The ITOS shall provide telemetry displays in real-time and offline modes. The ITOS will allow for the user to define display pages that include a telemetry variable, system variable, nontelemetry status information, and any local or global user-defined variables. The telemetry display capabilities shall include providing

a. General telemetry display capabilities

b. Telemetry display creation

c. Plotting

Requirement will be met.

4112-3.1

General Telemetry Display Capabilities

The ITOS shall provide general capabilities for all displays.

Requirement will be met.

4112-3.1.1

The ITOS shall accept a user request to bring up a display page and set the update rate to an integral number of seconds via a user directive. Telemetry-driven displays shall be user reconfigurable and have a default update of every 4 seconds. The maximum update rate shall be 1 second.

Requirement will be met.

4112-3.1.2

Displays shall be accessed through user directives.

Requirement will be met.

4112-3.1.3

Displays shall be cleared through user directives.

Requirement will be met.

4112-3.1.4

The ITOS shall, on user request, generate a display page snapshot at a user-specified time interval. A snapshot of a page can be generated even when a page is not active. Displays shall be printable by user directive or display snapshot. The main user window is not considered a display page and can not be snapped via user directive.

Requirement will be met.

4112-3.1.5

Displays shall be captured in an electronic file format and standard Internet file format on user request.

Requirement will be met.

4112-3.1.6

The ITOS shall support at least 25 display windows per workstation.

Requirement will be met.

4112-3.1.7

The ITOS shall allow the user to terminate a display page.

Requirement will be met.

4112-3.1.8

The ITOS shall provide the capability to support at least 50 parameters per display page.

Requirement will be met.

4112-3.2

Telemetry Display Creation

The ITOS shall support the creation of telemetry display pages. Telemetry display pages shall include, at user discretion, the following information:

a. Any telemetry mnemonic defined in the mission database or system variable.

b. Text description of the mnemonic.

c. Discrete states text.

d. Color designations for telemetry value text or for the discrete state result. When discrete state colors are defined in the database, those colors should be used as the default for a page definition file.

e. The capability to display values in binary, octal, hexadecimal, floating-point decimal, integer decimal, and American Standard Code for Information Interchange (ASCII).

f. Converted time values.

g. Quality flag for questionable quality data.

h. Flag for limits status. Value can be in limits, out of yellow limit, and out of red limits, or limits can be inhibited.

i. Static data flag or indicator.

j. Mnemonic units.

Requirement will be met.

4112-3.2.1

The ITOS shall display the raw value or EU value for each analog telemetry parameter displayed.

Requirement will be met.

4112-3.2.2

The ITOS shall display telemetry values that are being limit-checked with red/yellow, high/low limits in the color associated with the current limit state.

Requirement will be met.

4112-3.2.3

The ITOS shall recognize and notify when no data is available from any telemetry parameter.

Requirement will be met.

4112-3.3

Plotting

The ITOS shall validate data quality of a parameter before plotting. The ITOS will not plot questionable quality data.

Requirement will be met.

4112-3.3.1

The ITOS shall display up to five parameters (raw or EU-converted values) in each plot. Each Y-axis parameter shall be displayed with unique symbols and color.

Requirement will be met.

4112-3.3.2

The ITOS shall support two Y-axis scales (one on the left side of the plot and one on the right side).

Requirement will be met.

4112-3.3.3

Each scale shall be user adjustable in the plot definition file.

Requirement will be met.

4112-3.3.4

The ITOS system shall allow the user to specify the plot style to be either scatter or line plots.

Requirement will be met.

4112-3.3.5

The ITOS shall allow the user to display a minimum of 10 plots at a single time.

Requirement will be met.

4112-4

Spacecraft Limit Parameter Checking

The ITOS shall provide automatic limit checking on all parameters having limits defined within the mission database. Limit checking will be performed on both analog and discrete telemetry parameters. The ITOS will not perform limit checking on questionable quality data. Limit-checking capabilities shall include providing

a. Limit-checking counter reset

b. Limit violation guidelines

c. Limit violation event message

d. Limit violation display indication

e. Real-time limit changes

f. High/low limit value checks

Requirement will be met.

4112-4.1

Limit-Checking Reset

The ITOS shall reinitialize the limit-checking algorithm when telemetry processing is resumed or limit checking is reenacted.

Requirement will be met.

4112-4.2

Limit Violation Guidelines

The ITOS shall require two successive occurrences of a value that are outside of the normal limits before indicating that a limit violation has occurred.

Requirement will be met.

4112-4.3

Limit Violation Event Message

The ITOS shall provide a scrolling event message indicating that a limit violation has occurred.

Requirement will be met.

4112-4.4

Limit Violation Display Indication

The ITOS shall update telemetry displays to indicate that a telemetry value has exceeded a limit.

Requirement will be met.

4112-4.5

Real-Time Limit Changes

The ITOS shall accept temporary changes to limit processing in real time. These temporary changes include allowing the user to disable/enable limit-checking for one or all telemetry mnemonics and allowing the user to temporarily change the limit boundaries for individual telemetry mnemonics. The ITOS shall maintain real-time limit values until the mission support is terminated (i.e., hardware reset or software reboot).

Requirement will be met.

4112-4.6

High/Low Limit Value Check

The ITOS shall check the actual value of a telemetry parameter against the red and yellow limits associated with it and report limit violations to the user. Limits are specified

in the mission database. If limit checking is enabled for a telemetry parameter, the ITOS shall check the optional switch mnemonic associated with the high/low limit sets for this parameter to determine which high/low limit set to use.

A set of high/low limits consists of the following:

a. Red high limit

b. Red low limit

c. Yellow high limit

d. Yellow low limit

Requirement will be met.

4112-4.6.1

Up to two sets of high/low limits can be defined for each telemetry parameter. If two sets are defined for one parameter, the values of the switch mnemonics associated with the limit sets shall be checked to determine which limit set to use. The switch mnemonic is a mnemonic defined in the mission database.

Requirement will be met.

4112-5

Spacecraft Configuration Checking

The ITOS shall perform monitoring of the spacecraft configuration and report the results through the use of predefined values. The frequency of the checking will be based on a user-specified time interval. The ITOS will report configuration errors in the general events page. Spacecraft configuration checking capabilities shall include providing

a. Expected spacecraft configuration definition

b. Spacecraft configuration comparison

Requirement will be met.

4112-5.1

Expected Spacecraft Configuration Definition

The ITOS shall allow the user to define one or more spacecraft configurations that detail the expected state and/or value of at least *N* spacecraft telemetry mnemonics. Each configuration shall be identifiable by name.

Requirement will be met.

4112-5.2

Spacecraft Configuration Comparison

The ITOS shall, on user request, compare the expected spacecraft configuration in telemetry against spacecraft telemetry data. Questionable quality data shall not be used in the comparison.

Requirement will be met.

4112-5.2.1

The ITOS shall allow the user to initiate and terminate the monitoring of a named spacecraft configuration.

Requirement will be met.

4112-5.2.2

The ITOS shall allow at least 10 expected states to be monitored at the same time.

Requirement will be met.

4112-5.2.3

The ITOS shall be capable of displaying the names of the spacecraft configurations actively being monitored.

Requirement will be met.

4112-5.2.4

The ITOS shall allow the user to specify the rate at which an equation or condition within a spacecraft configuration is evaluated. The selectable rates shall include the following:

a. Data-driven evaluation: The evaluation shall be controlled by one of two methods:

   (1) Evaluate the expression when values for all mnemonics in it have been updated since the last evaluation, or when a second update occurs on at least one mnemonic value.

   (2) Evaluate the expression whenever one updated value has been received for any of the mnemonics in the expression.

b. Time interval evaluation: The expression or condition shall be evaluated every *N* milliseconds.

Requirement will be met.

4112-6

Sequential Prints

The ITOS shall extract specific data during a processing session. These data points may include any system variable, telemetry mnemonic, nontelemetry status value, and local or global user-defined variable. Each data point will include formatting information and indicate whether or not mission database conversions will be used. The ITOS will collect the data at user-defined rates. The ITOS shall collect the asynchronous data without dropping any data points. Output data files will be stored in ASCII. Sequential print capabilities shall include providing

a. Sequential print definition files

b. Sequential print output files

Requirement will be met.

4112-6.1

Sequential Print Definition Files

The ITOS shall allow the user to specify a sequential print definition file that includes the data point to be sampled, the EU/raw specifications, the data output, the sampling rates, and whether or not the data is quality flagged.

Requirement will be met.

4112-6.2

Sequential Print Files

The sequential print data files shall be designed for printed ASCII output.

Requirement will be met.

4112-6.2.1

The ITOS shall support collection of at least 40 data files/reports at one time.

Requirement will be met.

4112-6.2.2

The ITOS shall support the collection of an unlimited number of samples for each telemetry point in an active sequential print file.

Requirement will be met.

4112-6.2.3

The ITOS shall collect sampled telemetry data during real-time or offline processing.

Requirement will be met.

4112-6.2.4

The ITOS shall allow the user requesting a sequential print to select whether the set of telemetry parameters shall be printed only when a change occurs or at a fixed-time interval.

Requirement will be met.

4112-6.2.5

Each sequential print data file shall include an optional header with each telemetry parameter identified by a mnemonic or user-defined description.

Requirement will be met.

4112-6.2.6

Each data value shall be separated by a user-specified delimiter.

Requirement will be met.

4112-6.2.7

The sequential print output shall optionally be displayed, written to a file, or printed.

Requirement will be met.

4112-6.2.8

The ITOS shall include global variables that can be used in page displays, sequential prints, and Spacecraft Test and Operations Language (STOL) for packet receipt counts.

Requirement will be met.

4112-6.2.9

The ITOS shall perform autonomous FTP of image files to the PI facility (VC2, VC3, and VC4) once the CPIO extraction process is complete. The files will be transmitted via FTP with a “DONE” file, or the files will be given temporary file names during the FTP process.

Requirement will be met.

4112-7

Memory/Table File Dump Processing

The ITOS shall collect flight software and table dump images (VC5) from downlinked spacecraft telemetry. The load editor on the ITOS shall be capable of viewing table dump files using presupplied configuration parameters.

Figure 4100-1 indicates the general ITOS image data processing functional flow. Memory/table dump capabilities shall include providing

a. Dump image file receipt

b. Dump image report

c. Dump image transfer to the project

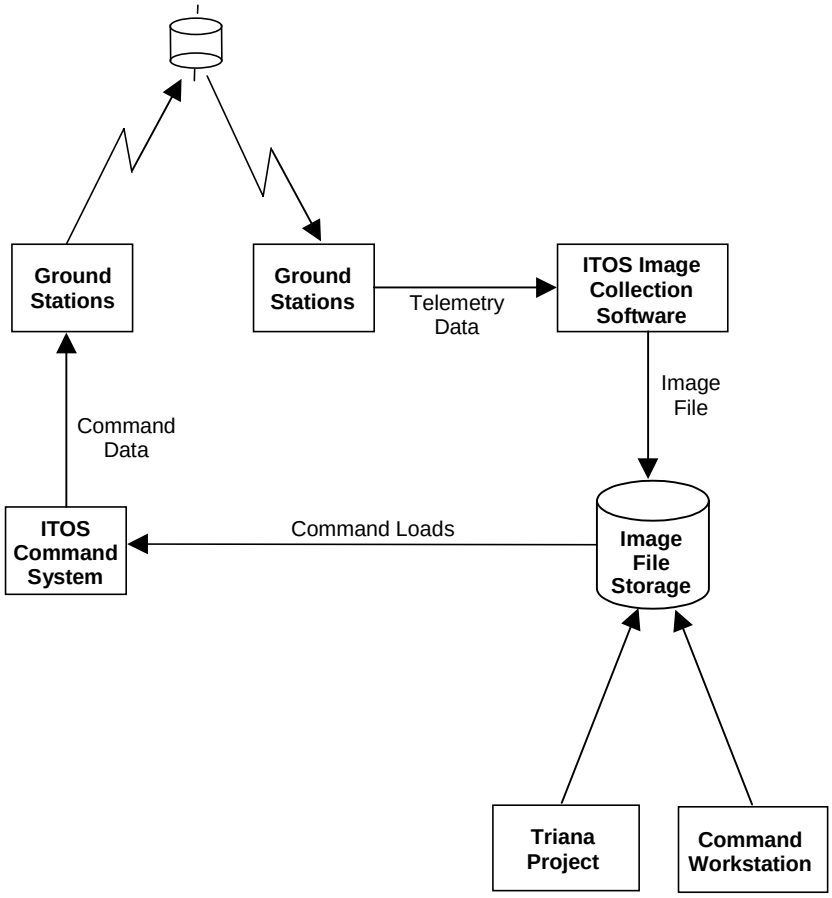


Figure 4100-1: ITOS Image Data Processing Function

Requirement will be met.

4112-7.1

Table File Collection

The ITOS shall receive spacecraft table flight software files. Each file received shall be stored as a separate downlinked image file. If the file name already exists, a sequence number will be appended to the name.

Requirement will be met.

4112-7.2

Memory Dumps

The ITOS shall receive a memory dump in an image file from the spacecraft. The dump file will default to an easily recognized name or to a user-defined name.

Requirement will be met.

4112-7.3

File Report

The ITOS shall generate an image file report containing the contents of the image file.

Requirement will be met

4112-7.4

Table Dump Display

The ITOS shall be able to display table dumps.

Requirement will be met.

4112-8

Event Messages

The ITOS shall provide event messages to keep the MOT informed of the ITOS, spacecraft, and command process status during real-time passes, and provide a chronology of events for postpass reconstruction and analysis of real-time activities. Event message capabilities shall include providing

a. Time-tagged event messages

b. Event text

c. Event message types

d. Event message archive

Requirement will be met.

4112-8.1

Time-Tagged Event Messages

Each event message shall have a timetag field that has the day of year, hour, minutes, and seconds for each event. The timetag shall be based on UTC at time of occurrence for ground system and command-related events. For telemetry-related events, the timetag shall be based on the packet time. The timetag field will consist of day of year, hours, minutes, and seconds.

Requirement will be met.

4112-8.2

Event Text

Each event message shall provide a clear and unambiguous text description of the event in a message field.

Requirement will be met.

4112-8.3

Event Message Types

The ITOS shall be able to enable, disable, or filter event messages by type. Each event message shall be assigned a type (e.g., ITOS system messages, command uplink messages, telemetry limit messages).

Requirement will be met.

4112-8.4

Event Message Archive

All events shall be logged in a history file and be available for reference after the real-time event.

Requirement will be met.

4112-8.4.1

The ITOS shall record all event messages to the event history file in the chronological order in which they are received by the logging system.

Requirement will be met.

4112-8.4.2

The ITOS shall provide the capability to create and open a new events history file or close an events history file on user request.

Requirement will be met.

4112-9

Spacecraft Event Messages Collection

The ITOS shall capture, collect, and display spacecraft event messages generated by the spacecraft subsystems. These spacecraft event messages will appear in the telemetry stream as several unique packet types, as defined by the application ID in the packet header. A scrolling display of each event message packet shall be generated.

Requirement will be met.

4120-1

MOC-to-Spacecraft Interface

NISN shall provide the interface from the ITOS to the spacecraft I&T GSE and the operations ground stations. This interface will be used to verify end-to-end system requirements, support operations testing, and support spacecraft operations. The ITOS will interface with the I&T system during operations testing and the ground stations during spacecraft operations. Spacecraft commanding will conform to the CCSDS Blue Book COP-1 protocol. MOC-to-spacecraft interface capabilities shall include the following:

a. Spacecraft command generation

b. Spacecraft command buffer and sequence control

c. Spacecraft command transmission

d. Spacecraft command verification

e. Spacecraft table and memory load uplink

Requirement will be met.

4121-1

Spacecraft Command Generation Overview

The ITOS shall format real-time commands, spacecraft command loads, and CCSDS bypass and control commands into the appropriate data structures and transmit them, through NISN, to the ground station for uplink to the spacecraft. The ITOS shall verify receipt of the commands by the spacecraft and inform the user of the command uplink status. The CCSDS telecommand standard data structures and the relationships between these structures are described in Section 2030 of the *CCSDS Recommendation for Space Data System Standards*, and in the *Triana T&C Handbook, Volume I.*

Requirement will be met.

4121-2

Real-Time Commands

The ITOS shall generate real-time commands from a combination of database definitions and user input. Real-time command capabilities shall include providing

a. Telecommand packets

b. Telecommand transfer frames

c. Automatic transfer frame header sequence numbers

d. User-defined transfer frame header sequence numbers

e. Transfer frame conversions

Requirement will be met.

4121-2.1

Telecommand Packets

The ITOS shall construct telecommand packets for real-time commands. The CCSDS telecommand packet format is described in the *Triana T&C Handbook, Volume I.*

Requirement will be met.

4121-2.2

Telecommand Transfer Frames

The ITOS shall insert CCSDS telecommand packets containing real-time commands, command workstation-generated load commands, CCSDS control commands, and special hardware commands into the CCSDS telecommand transfer frames. Each transfer frame contains one telecommand packet and, therefore, one command. The format of the telecommand transfer frame is described in the *Triana T&C Handbook, Volume I.*

Requirement will be met.

4121-2.3

Automatic Transfer Frame Header Sequence Number

The transfer frame header sequence number for the first command of a pass shall be derived from the report value field of the CLCW in the telemetry transfer frame. Subsequent frame sequence numbers optionally will be computed automatically by incrementing the frame sequence number from the previous transfer frame (until direction to derive the frame sequence number from the CLCW again or by user key-in).

Requirement will be met.

4121-2.4

User Defined Transfer Frame Header Sequence Number

The ITOS shall allow the user to optionally set transfer frame header sequence number. The command request that set the telecommand transfer frame header sequence number to a user-specified value shall be accepted and syntactically validated.

Requirement will be met.

4121-2.5

Transfer Frame Conversion

The ITOS shall convert at least one telecommand transfer frame that will be packed into one CLTU into CCSDS telecommand code blocks.

Requirement will be met.

4121-3

Spacecraft Command Loads

The ITOS shall accept spacecraft command loads generated by the Triana command workstation for uplink.

Requirement will be met.

4121-4

CCSDS Control Commands

The ITOS shall generate “Next Expected Sequence Number RESET” and “Command Transmission UNLOCK” CCSDS control commands. CCSDS control commands should not be entered in the command buffer, and should not be automatically retransmitted. CCSDS control command capabilities shall include providing

a. Control command transmission status

b. A control command transfer frame

Requirement will be met.

4121-4.1

Control Command Transmission Status

The ITOS shall display the CCSDS control command transmission status on the command transmission and verification display.

Requirement will be met.

4121-4.2

Control Command Transfer Frame

The ITOS shall transmit CCSDS control commands in a unique transfer frame with a separate CLTU.

Requirement will be met.

4121-5

Spacecraft Hardware Command

The ITOS shall generate a spacecraft hardware command as defined in the *Triana Telemetry and Control Handbook, Volume 1*. The spacecraft hardware command should not be entered in the command buffer, and should not be automatically retransmitted. The spacecraft receipt and verification processing will not be performed.

Requirement will be met.

4121-6

Command Mode Updates

The ITOS shall allow the user to update command modes via a user directive. Command mode update capabilities shall include providing:

a. Command receipt verification

b. Command verification delay

c. Command rate metering

Requirement will be met.

4121-6.1

Command Receipt Verification

The ITOS shall allow the user to enable or disable spacecraft command receipt verification.

Requirement will be met.

4121-6.2

Command Verification Delay

The ITOS shall allow the user to set the command verification delay. The default verification delay will be user defined. The command verification process will time out after the verification delay.

Requirement will be met.

4121-6.3

The ITOS shall allow the user to set the delay rate between commands.

Requirement will be met.

4122-1

Spacecraft Command Buffer and Sequence Control Overview

The ITOS shall accept and evaluate spacecraft commanding requests that control the generation and uplink of real-time commands, table and flight software memory loads, and CCSDS bypass and control commands.

Requirement will be met.

4122-2

Command Requests

The ITOS shall accept command request from the MOT in mnemonic format through the command directive or in a raw hexadecimal command pattern in packet or transfer frame format. Command requests will include requests to generate commands, uplink commands, and manage the commanding environment in the ITOS. The mission database will contain the information required to build the command. Command request capabilities shall include providing command

a. Validation event messages

b. Mnemonic and submnemonic validation

Requirement will be met.

4122-2.1

Command Validation Event Messages

The ITOS shall validate command requests for syntax. The ITOS shall generate an event message for every command transmission. For an invalid request, the ITOS shall generate an event message that indicates the invalid condition. The event message shall contain the UTC of the command transmission. The output of the event message shall also include the bit structure of the transfer frame in hexadecimal.

Requirement will be met.

4122-2.2

Command Mnemonic and Submnemonic Validation

The ITOS shall validate all command mnemonics and submnemonics and issue an error message if the specified command is not found in the database.

Requirement will be met.

4122-2.2.1

The ITOS shall verify that a valid command mnemonic was specified in a real-time command request by checking it against the list of valid command mnemonics in the

database. If a specified mnemonic is not found in the database, the ITOS will generate an error message.

Requirement will be met.

4122-2.2.2

The ITOS shall verify that a valid command submnemonic was specified in a real-time command request by checking it against the list of valid command submnemonics in the database. If a specified submnemonic is not found in the database, the ITOS will generate an error message.

Requirement will be met.

4122-3

Criticality Checks

The ITOS shall perform criticality checks on each real-time command. A criticality indicator will be associated with each command in the database. For critical commands, the ITOS shall issue a prompt to the user terminal indicating that the command to be uplinked is critical. User intervention shall be required to permit transmission to the spacecraft.

Requirement will be met.

4122-4

Command Submnemonics

Submnemonics shall be used to reference subfields, when applicable. Submnemonics shall be of either fixed or variable types. Command submnemonics capabilities shall include providing

a. User input conversions

b. Automatic conversion override

c. Mandatory subfields

Requirement will be met.

4122-4.1

User Input Conversions

The ITOS shall convert the user input to the database-specified data type (e.g., unsigned long integer) to build the command packet. The ITOS shall not provide unit conversions, such as polynomial calibrations or other “action” conversions, for subfield values.

Requirement will be met.

4122-4.2

Automatic Conversion Override

The ITOS shall provide for the automatic database conversion of subfields in a real-time commanding request to be overridden by entering the values as raw counts (e.g., hexadecimal, octal, binary) as denoted by the prefix (e.g., X'12', H'12', O'22', B'10010').

Requirement will be met.

4122-4.3

Mandatory Subfields

A flag shall be present in the database for each subfield to indicate whether the subfield is mandatory. If a mandatory subfield is omitted, the user shall be prompted to supply that subfield before transmission.

Requirement will be met.

4122-5

Command-Operating Modes

The ITOS shall provide two different command-operating modes that shall be user-controlled through user directives. Command-operating mode capabilities shall include providing

a. A one-step mode

b. A two-step mode

c. Default values

d. Parameter setting

e. Command mode request validation

Requirement will be met.

4122-5.1

One-Step Mode

When commanding in one-step mode, the ITOS shall immediately transmit the command.

Requirement will be met.

4122-5.2

Two-Step Mode

When commanding in two-step mode, the ITOS shall move the real-time command to a command buffer after validation. A separate user directive is required to begin transmission of the command buffer contents.

Requirement will be met.

4122-5.3

Default Values

The ITOS shall provide default value for each command mode parameter.

Requirement will be met.

4122-5.4

Parameter Setting

The ITOS shall issue an event message that indicates the updated command mode parameter setting.

Requirement will be met.

4122-5.5

Command Mode Request Validation

The ITOS shall verify that the command mode update request is valid for the current command environment (e.g., the user can not change from one-step commanding to two-step commanding mode while a load is in progress). For an invalid command mode update request, the ITOS will issue an error message that indicates the invalid condition.

Requirement will be met.

4122-6

COP-1 Bypass Commanding

The ITOS shall allow the user to enable or disable COP-1 bypass commanding.

Requirement will be met.

4122-7

Buffer Clearing

The ITOS shall provide the capability to clear the command buffer in response to a user directive.

Requirement will be met.

4123-1

Spacecraft Command Transmission Overview

The ITOS shall, on user direction, initiate the uplink of spacecraft commands. The ITOS shall examine and respond to the contents of the CLCW in the downlinked telemetry. The ITOS shall maintain and make available for display statistics on the uplink status.

Requirement will be met.

4123-2

Lockout Flag Processing

If the lockout flag in the CLCW is set, the ITOS shall generate an event message stating that the lockout flag is set. The command transmission status and verification display page shall be updated, and the command transmission shall be stopped. The command buffer shall not be cleared.

Requirement will be met.

4124-1

Spacecraft Command Verification Overview

The ITOS shall perform spacecraft command receipt processing (all command types) on a command buffer basis following COP-1 protocol and the Triana implementation of the CCSDS 128 command sliding window.

Requirement will be met.

4124-2

Command Receipt Verification

Command receipt verification capabilities shall include providing

a. Verification enable/disable

b. Command status

c. Verification delay

Requirement will be met.

4124-2.1

Command Verification Enable/Disable

The ITOS shall allow the user to enable or disable spacecraft receipt verification.

Requirement will be met.

4124-2.2

Command Status

If command verification is successful, the command transmission status and verification display page shall be updated.

Requirement will be met.

4124-2.3

Command Verification Delay

The ITOS shall allow the user to set the command verification delay. The command verification process will time out after the verification delay.

Requirement will be met.

4124-3

Frame Acceptance and Reporting Mechanism

The ITOS shall follow the FARM type B portion of the COP-1 protocol.

Requirement will be met.

4124-4

Command Retransmission

The ITOS shall, if command retransmission is enabled, automatically retransmit commands not verified by a user-defined command timeout limit. The ITOS shall transmit a command up to three times (one original transmission and two retransmissions). Command retransmission capabilities shall include providing

a. Retransmit requests

b. Retransmit flag indication

c. Command status

d. Automatic transmissions

Requirement will be met.

4124-4.1

Retransmit Request

The ITOS shall retransmit IP command packets in response to a retransmit request from the user. Commands that have already been verified are not available for retransmission.

Requirement will be met.

4124-4.2

Retransmit Flag Indication

If the retransmit flag in the CLCW is set, the ITOS shall generate an event message stating that the retransmit flag is set.

Requirement will be met.

4124-4.3

Command Status

If the retransmit flag in the CLCW is set, the ITOS shall update the command transmission status and verification display page.

Requirement will be met.

4124-4.4

Automatic Transmissions

If the retransmit flag in the CLCW is set, the automatic retransmission is enabled, and the total number of transmissions is less than the user-defined value, the ITOS shall transmit the transfer frame with the frame sequence number equal to CLCW report value. If the designated transfer frame is not in the command buffer, the ITOS shall notify the user through an event message, and the command transmission shall be stopped. The command buffer shall not be cleared.

Requirement will be met.

4124-5

Receipt Verification Failure

The ITOS shall terminate the command transmission process if spacecraft command receipt verification does not occur after the user-selected number of retransmissions, and the user shall be notified of the verification status with an event message. The command buffer shall not be cleared. The process shall await further user action.

Requirement will be met.

4125-1

Spacecraft Table and Memory Loads Uplink Overview

The ITOS shall be responsible for the uplink of spacecraft table and flight software memory loads.

Requirement will be met.

4125-2

Load Generation

The ITOS shall build the uplink command load in response to a load directive. An uplink command load shall contain the commands for a single command load. The ITOS shall extract the commands from the command load and create the CCSDS telecommand data structures.

Requirement will be met.

4125-3

Load Transmission and Verification

The ITOS shall process spacecraft transmission and receipt verification of command loads in the same manner as user-issued commands.

Requirement will be met.

4130-1

Mission Planning and Scheduling Requirements

The command workstation shall provide the interface between external elements and the MOC for accepting command inputs. The command workstation shall be used to manage the onboard stored command processor (SCP) and build command scripts for SCP execution. The workstation shall accept inputs, process them, and combine them with other inputs to create command scripts to be sent to the spacecraft. Mission planning and scheduling capabilities shall include the following:

a. Command script input

b. Command script generation

c. Command script reports

Requirement will be met.

4132-1

Command Script Input Overview

The MOT shall use the command workstation to use routine information in generating command scripts.

Requirement will be met.

4132-2

Database

The command workstation shall use the identical telemetry and command database that is used for ITOS.

Requirement will be met.

4132-3

File inputs

The command workstation shall be able to use STOL procedures or a text file as input to generate script files.

Requirement will be met.

4133-1

Command Script Generation Overview

The command workstation shall generate SCP command scripts.

Requirement will be met.

4133-2

Normal Command Script Generation

The command script shall consist of spacecraft and external requests. The command workstation will translate STOL procedure and text file command inputs into flight software command scripts for execution onboard the spacecraft.

Requirement will be met.

4133-2.1

Normal Command Script Construction

The command workstation shall construct the normal command script within 15 minutes of initiation.

Requirement will be met.

4133-3

Script Generation Error Checking

The command workstation shall perform error checking of all loads as follows:

a. Perform STOL syntax checking of all loads

b. Any illegal telemetry or command mnemonic

Requirement will be met.

4134-1

Command Reports Overview

The command workstation shall produce reports corresponding to the command scripts generation process.

a. Syntax errors

b. C++ code generation errors

c. Compiling errors

d. Resulting files with filenames

e. Illegal commands/telemetry mnemonics

Requirement will be met.

4140-1

User Interaction

The MOC shall provide user interaction for MOT control over the MOC systems. The interaction shall include input via keyboard and mouse. The user interaction shall include the following:

a. A user interface language

b. Automated procedures

Requirement will be met.

4141-1

User Interface Language Overview

The MOC shall provide a user interface language for system configuration, telemetry processing, and commanding.

Requirement will be met.

4141-2

Parsing and Syntax Checking

The interface language shall provide parsing and syntax checking directives, informing the user as appropriate.

Requirement will be met.

4141-3

Long- and Short-Form Entry

The interface language shall provide a long and short form of directive entry.

Requirement will be met.

4141-4

Optional Prompt Mode

The interface language shall provide an optional prompt mode for users.

Requirement will be met.

4141-5

Telemetry and System Value Accessing

The interface language shall provide access to current telemetry and system values, allowing observations of values in raw or converted form.

Requirement will be met.

4141-6

Telemetry Mnemonic Values Insertion

The interface language shall provide the ability to insert a value into a telemetry mnemonic.

Requirement will be met.

4142-1

Automated Procedures Overview

The MOC shall provide an automated procedure capability, which will include logic and arithmetic capabilities.

Requirement will be met.

4142-2

Procedure Generations

The MOC automated procedure capability shall allow the MOT to build procedures. The number of procedures should be limited only by disk space.

Requirement will be met.

4142-3

Parameter Passing

The MOC automated procedure capability shall allow procedure parameter passing.

Requirement will be met.

4142-4

Local and Global Variables

The MOC automated procedure capability shall provide local and global variables.

Requirement will be met.

4142-5

Arithmetic Capabilities

The MOC automated procedure capability shall provide arithmetic capabilities using local and global variables, telemetry values, system variables, and constants.

Requirement will be met.

4142-6

Logic Capabilities

The MOC automated procedure capability shall provide logic capabilities to allow procedure control and conditional logic paths. Logic conditions should be based on local and global variables, passed parameters, telemetry values, and system variables.

Requirement will be met.

4142-7

Editing and Listing Capabilities

The MOC automated procedure capability shall provide editing and listing capabilities, including typical file maintenance.

Requirement will be met.

4142-8

Decision Logic Capabilities

The MOC automated procedure capability shall provide decision logic capabilities.

Requirement will be met.

4142-9

Comment Capability

The automated procedure capability shall provide comment capability.

Requirement will be met.

4142-10

Procedure Control Directives

The automated procedure capability shall provide procedure control directives to allow starting, stopping, and branching options.

Requirement will be met.

4142-11

Data Access

The MOC shall provide all real-time telemetry data for use in automated procedures and real-time requests. The latest telemetry value shall be used in all automated procedures and requests, including conditional waits, IF-THEN-ELSE logic, raw value requests, and arithmetic calculations.

Requirement will be met.

4142-12

Directive Validation

The MOC shall validate all directives to ensure proper format and user permission.

Requirement will be met.

4142-13

Procedure Execution

The MOC shall execute procedures and report both the acceptance and completion of the procedures to the user.

Requirement will be met.

4142-14

Directive Execution

The MOC shall execute directives and report both the acceptance and completion of the directive to the user.

Requirement will be met.

4142-15

Absolute Time Wait

The MOC shall execute procedures that include the capability to wait until an absolute time before proceeding.

Requirement will be met.

4142-16

ITOS Packet Count Resets

The MOC shall be able to enter a directive in ITOS to reset packet-received totals to zero without affecting other telemetry functions.

Requirement will be met.

4150-1

General

The Data Trending & Analysis System (DTAS) shall perform all offline trending functions. These functions shall include storage of a subset of spacecraft telemetry and ground-system-generated mnemonic values, data analysis, and plotting. The DTAS shall perform the analysis and plotting functions without requiring MOT intervention for non-MOT users. The DTAS shall provide the ability to export data. The DTAS shall be able to retain configuration information from one session to the next.

Requirement will be met.

4151-1

Data Archiving

The DTAS shall be able to perform the following:

a. Store and retrieve the data values from up to 525 selected mnemonics between 7 and 48 days, depending on the size of the data set

b. Store and retrieve data trend products for the life of the mission

c. Ingest data at operator request

d. Ingest data through automated procedures

e. Generate data trend products at operator request

f. Generate data trend products through automated procedures

Requirement will be met.

4152-1

User Access Overview

The DTAS shall provide access to the full trending capabilities. Trending data user interface capabilities shall include providing

a. Client/server application

b. World Wide Web accessibility

c. User access security

Requirement will be met.

4152-1.1

Client/Server Application

a. The DTAS shall provide to users, on request, client applications that provide access to the full capabilities of the DTAS.

b. The DTAS client applications shall be easily installed and used on any personal computer that meets or exceeds the target system described in Requirement 4152-1.2.

Requirement will be met.

4152-1.2

Client Target System

The DTAS client application shall run on a user-provided personal computer that meets or exceeds the following specifications:

a. 100-MHz Pentium processor

b. 32-megabyte (MB) random access memory (RAM)

c. 60-MB available hard disk space

d. A network connection to the server

e. Microsoft Windows 9x or NT 4.0 operating system

Requirement will be met.

4152-2.1

World Wide Web Application

a. The DTAS shall be accessible using Web browsers (Internet Explorer 3.x or above, Netscape 4.x or above, or any other browser with equivalent functionality).

b. The DTAS shall provide Web access to the DTAS data and plots. The user shall be able to display data or a plot versus time of any mnemonic in the trending database. None of the plot manipulation or data analysis functions need to be supported through the Web interface.

Requirement will be met.

4152-2.2

Target System

The DTAS shall support any system that supports the Web browser applications described in Requirement 4152-2.1 and has a suitable network connection.

Requirement will be met.

4152-3

Security

User access to the DTAS shall be password controlled.

Requirement will be met.

4153-1

Data Analysis Overview

Trending data analysis capabilities shall be used in the client/server mode only and include providing data

a. Selection

b. Analysis

c. Display and reporting

Requirement will be met.

4153-1.1

Data Selection

The DTAS shall allow the user to perform the following:

a. Select up to 10 mnemonic values to analyze

b. Select a time domain for the selected mnemonic values

c. Filter the data set based upon the mnemonic values using simple conditionals (e.g., greater than constant, less than constant)

Requirement will be met.

4153-1.2

Data Analysis

The DTAS shall allow the user to perform the following:

a. A maximum, minimum, and mean value analysis of the selected data set

b. A spacecraft power analysis over a user-selected time domain

Requirement will be met.

4153-1.3

Data Display and Reporting

The DTAS shall allow the user to perform the following:

a. View the selected data set in the form of tables

b. Print a report of the selected data set

c. Save a report of the selected data set to a file

Requirement will be met.

4154-1

Data Plotting – General

The DTAS shall allow the user to display line plots of the data set selected for analysis.

Requirement will be met.

4154-1.1

Function Plots

In addition to plotting up to 10 mnemonic values, the DTAS shall allow the user to create up to 4 function plots. They shall be one of the following:

a. Data values

b. Maximum value

c. Minimum value

d. Mean of mnemonic values

e. Mean of any number of existing series

f. Addition of any number of existing series together

g. Subtraction of any number of existing series from one series

h. Product of any number of existing series

Requirement will be met.

4154-1.2

Axis Control

The DTAS shall provide Y-axis and X-axis controls.

Requirement will be met.

4154-1.2.1

Y-axis

a. The DTAS shall allow the user to define up to two Y-axes.

b. The DTAS shall allow the user to set scales to be linear or logarithmic.

c. The DTAS shall allow the user to select scale ranges to be set automatically or manually.

Requirement will be met.

4154-1.2.2

X-axis

The DTAS shall allow the user to define up to two X-axes. For plots versus time, the following apply:

a. Scales will be linear.

b. The DTAS shall allow the user to select scale ranges to be set automatically or manually.

For mnemonic value versus value plots, the following apply:

a. The DTAS shall allow the user to set scales to be linear or logarithmic.

b. The DTAS shall allow the user to select scale ranges to be set automatically or manually.

Requirement will be met.

4154-1.3

Plot Manipulation

The DTAS shall allow the user to scroll through and zoom the charts.

Requirement will be met.

4154-1.4

Chart Reporting

a. The DTAS shall allow the user to print a report of the chart.

b. The DTAS shall allow the user to save a report of the chart to a file.

Requirement will be met.

4155-1

Data Export

The DTAS shall provide for exporting the selected data set to Microsoft Excel, Version 7 or 8, for further analysis. (Excel must already be installed on the user's computer.)

Requirement will be met.

4156-1

System Configuration Control

The DTAS shall allow the following:

a. Current configuration to be saved to a file

b. Saved configurations to be reloaded

Requirement will be met.

4160-1

Autonomous Spacecraft Operations Overview

The ITOS shall permit autonomous spacecraft pass operations without the presence of the MOT.

Requirement will be met.

4160-2

IP Connection

The ITOS shall autonomously form IP socket connections with ground stations upon ground-station- or Network Management Center (NMC)-initiated action.

Requirement will be met.

4160-3

Data Storage

The ITOS shall autonomously receive and store VC0, VC1, VC2, VC3, VC4, and VC5 data received via FTP or a socket connection to the ground station. VC0, VC1, VC2, VC4, and VC5 data will be received in real time, while VC3 data will be received postpass via FTP.

Requirement will be met.

4160-4

Data Transfer

The ITOS shall autonomously transfer (via socket connection) VC0 packets to the International Solar-Terrestrial Physics (ISTP) Program Central Data Handling Facility (CDHF) and TSOC, and VC2 and VC4 images (via FTP or socket connection) to TSOC. Postpass VC3 image files shall autonomously transfer (via FTP) to the TSOC.

Requirement will be met.

4160-4.1

The ITOS shall recognize broken socket connections with TSOC and ISTP CDHF and autonomously attempt to reestablish those connections.

4160-5

Standard STOL Procedures

The ITOS shall permit autonomous execution of standard STOL procedures and configuration monitor procedures at a specified UTC time.

Requirement will be met.

4160-6

Configuration Monitor Procedures

The ITOS shall permit autonomous execution of configuration monitor files. Configuration monitor files shall allow the MOT to create state-modeling logic that will permit spacecraft subsystem state-checking and monitoring.

Requirement will be met.

4160-7

Remote Login

The MOC shall provide the capability for the MOT to log in remotely, download archived VC0 data, and display pages to be viewed over the Internet.

Requirement will be met.

4160-8

The ITOS shall have the ability to receive and process station status packets from multiple stations simultaneously.

Requirement will be met.

4160-9

The ITOS shall be able to replay archived data files at a rate of up to 1 Mbps with no impact to sequential print or plot processing.

Requirement will be met.

4160-10

The ITOS shall be able to decommutate the raw transfer frame time.

Requirement will be met.

4160-11

The ITOS shall be able to decommutate the Earth received time located in the SMEX telemetry header.

4160-12

Virtual Mission Operations Control/Spacecraft Emergency Response System (VMOC/SERS) Overview

The VMOC/SERS shall monitor autonomous spacecraft pass operations and ground systems without the presence of the MOT.

Requirement will be met.

4160-12.1

The VMOC/SERS will be located on the Open IP Operational Network (IONET) and be accessible by an Internet Web browser or Lotus Notes.

Requirement will be met.

4160-12.2

The VMOC/SERS Internet server will have different levels of user privileges:

- Open—Browse pages and log files
- User-level—Edit specified pages and files
- Manager—Full access

Requirement will be met.

4160-12.3

The VMOC/SERS will maintain the I&T and operational databases of all spacecraft and ground anomalies for the life of the mission.

Requirement will be met.

4160-12.4

The VMOC/SERS will be capable of ingesting operations schedules from the USN and DSN.

Requirement will be met.

4160-12.5

The VMOC/SERS will be capable of receiving ITOS log files every 15 minutes.

Requirement will be met.

4160-12.5.1

The VMOC/SERS will process ITOS log files within 5 minutes using the regular event processor (REP).

Requirement will be met.

4160-12.5.2

The VMOC/SERS ground monitor (GM) will alert MOT personnel if an ITOS log file has not been received for a specified time period.

Requirement will be met.

4160-12.6

The VMOC/SERS system monitor (SM) will verify that operational systems are working.

Requirement will be met.

4160-12.6.1

The VMOC/SERS will create pass summaries from multiple ITOS log files.

Requirement will be met.

4160-12.6.2

The VMOC/SERS pass summaries will include the following:

- User-identified telemetry mnemonics
- Procedures executed
- Spacecraft event messages
- ITOS event messages
- Commands sent
- Limit and configuration monitor violations

Requirement will be met.

4160-12.6.3

The VMOC/SERS will alert appropriate MOT personnel if a ground system cannot be reached.

Requirement will be met.

4160-12.7

The VMOC/SERS will check all incoming log files for matches to a user-specified list of keywords.

Requirement will be met.

4160-12.7.1

The VMOC/SERS will be capable of monitoring user-input parameters and alerting MOT members if the specified time has elapsed.

Requirement will be met.

4160-12.7.2

The VMOC/SERS will create an incident report if an alert is identified by the GM, SM, or REP.

Requirement will be met.

4160-12.8

MOT Paging

The VMOC/SERS shall be capable of paging designated MOT members in the event that a configuration monitor procedure detects out-of-limit or unsafe conditions for one or more spacecraft subsystems or an undesirable ground system condition.

Requirement will be met.

4160-12.8.1

The VMOC/SERS will be capable of alerting the MOT using a prioritized list of MOT members through one of the following methods:

- Alphanumeric paging
- Electronic mail

Requirement will be met.

4200-1

Flight Software Maintenance

Flight Software Maintenance shall include the Software Development and Validation Facility (SDVF) development (Section 4210) and flight software maintenance (Section 4220). During early mission and normal and contingency operations, the Flight Software Maintenance Facility (FSMF) shall generate, validate, and transfer flight software memory and table images to the SMEX/Triana MOC for uplink.

Requirement will be met.

4210-1

Flight Software Development

The Triana Project shall provide the flight maintenance group with a fully validated and documented SDVF that represents the spacecraft real-time environment. This facility will be used to validate any flight software modification prior to uplink.

Requirement will be met.

4220-1

Flight Software Maintenance - General

Flight software maintenance services shall begin at launch plus 3 months or orbital verification, whichever occurs last, and continue throughout the mission life. The Triana Project will provide the flight software maintenance group with a full functional and debugged flight system 1 year prior to early mission operations. Flight software updates will be limited to those necessitated by contingencies, anomalous behavior, or some desired enhancement.

Requirement will be met.

4220-2

Maintain Code

The flight software maintenance group shall provide the following services for maintaining code and documentation:

a. Maintain configured flight software and build environment

b. Maintain images of onboard spacecraft memory and tables

c. Maintain documentation of any software modifications, including test procedures and results

Requirement will be met.

4220-3

Flight Software Modifications

In order to provide necessary flight software modifications, the flight software maintenance group shall perform the following:

a. Conduct the flight software Configuration Control Board (CCB)

b. Update flight code as needed to respond to contingencies, anomalies, desired enhancements, or changes in operations

c. Create test procedures and validate flight software modifications in the SDVF

Requirement will be met.

4220-4

Interface With MOC

The flight software maintenance group shall interface with the MOC for load and dump images. The flight software maintenance group shall

a. Provide properly formatted memory and table images to the MOC for load generation and uplink

b. Provide analysis of dump images received from the MOC for anomaly investigation

c. Provide installation procedures to the MOC for installing flight software modifications

Requirement will be met.

4220-5

Provide Support to the MOT

In support of the MOT, the flight software maintenance group shall

a. Support integration and test activities by providing memory and table images, as well as dump analysis

b. Work with the MOT to discuss anomaly investigations and discuss potential flight software changes and their impacts

Requirement will be met.

4220-6

Maintain Flight Software Maintenance Equipment (FSME)

The flight software maintenance group shall

a. Acquire commercial supporting equipment, compilers, and other commercial software and integrating hardware, as necessary. The Triana Project will provide custom hardware such as ETUs.

b. Develop and maintain custom software required for testing software modifications and performing analysis

Requirement will be met.

4300-1

MOC Facilities

The Triana mission shall utilize a single MOT and the SMEX operations facilities to support on-orbit and on-ground testing. The SMEX MOC facilities shall allow the MOT to perform all required operations from one physical location. Additionally, the MOC facilities shall allow support personnel to perform L&EO operations, testing, and simulations concurrent with ongoing mission operations. MOC facilities capabilities shall include MOC general resources and functional areas.

Requirement will be met.

4310-1

MOC General Resources

The MOC shall be sized so that general resource requirements can be met.

Requirement will be met.

4310-2

Uninterruptable Power Source

The MOC shall include an uninterruptable power source to provide the MOC systems with an uninterrupted supply of power in the event of a utility power outage.

Requirement will be met.

4310-3

Reproduction

The MOC shall include a copier to reproduce reports, memorandums, printouts, and plots as required.

Requirement will be met.

4310-4

Facsimiles

The MOC shall include a facsimile machine and associated data line to fax reports as required.

Requirement will be met.

4310-5

Printers

The MOC shall include a black/white LaserJet printer and color inkjet printer to generate reports, printouts, and plots as required.

Requirement will be met.

4320-1

MOC Functional Areas

The MOC functional area capabilities shall include providing

a. Mission Operations Facility

b. Collocated MOT Offices

c. Early Mission Support Room

Requirement will be met.

4321-1

Mission Operations Facility Overview

The MOC facility shall be used for detailed pass planning; real-time operations support; postpass activities; spacecraft dump data processing and evaluation; and database and procedure development and maintenance. The MOC facility shall also be used to conduct mission planning and scheduling, attitude support, trajectory support, and data trending. The MOC shall be available 7 days per week, 24 hours per day.

Requirement will be met.

4321-2

Mission Operations Facility Layout

The MOC facility shall be designed such that the MOT has MOC resources, communications status displays, and indicators at their immediate disposal to allow for easy and quick assessments of the real-time system performance.

Requirement will be met.

4321-3

Controller Positions

The facility shall include workstations with MOC systems to allow telemetry processing, spacecraft monitoring, spacecraft control in real-time, mission planning, and offline analysis. Controller position capabilities shall include providing

a. Color displays

b. Clock displays

c. Interface devices

d. Voice communication panels

e. Documentation storage

Requirement will be met.

4321-3.1

Color Displays

Each controller position shall have a graphic color display.

Requirement will be met.

4321-3.2

Clock Displays

Each controller position shall have an unobstructed view of UTC and countdown clock displays.

Requirement will be met.

4321-3.3

Interface Devices

Each controller position shall have a keyboard and any other input devices necessary to interface with the real-time MOC systems.

Requirement will be met.

4321-3.4

Voice Communications Panels

Each controller position shall have access to a voice communications panel (including handset and headset options, speaker options, and volume control) containing required closed-circuit loop (CCL), switching, conferencing, and monitoring arrangement (SCAMA), and public phone lines.

Requirement will be met.

4321-3.5

Documentation Storage

Each controller position shall have easily accessible storage space for documentation, printouts, and papers.

Requirement will be met.

4321-4

Information Display Area

The MOC facility shall include a marker board and an area for posting messages, plots, and other information.

Requirement will be met.

4322-1

MOT Offices Overview

The MOT offices shall include furniture, workstations, and phones to support the MOT.

Requirement will be met.

4323-1

Early Mission Support Room

The Early Mission Support Room shall be used primarily for ground system testing and to provide addition console positions during early mission operations. These early mission phases include L&EO, spacecraft deployment, cruise, and orbit insertion. The Early Mission Support Room shall be available 7 days per week, 24 hours per day.

Requirement will be met.

4323-2

Early Mission Support Room Layout

The Early Mission Support Room shall be designed such that personnel have MOC resources, communications status displays, and indicators at their immediate disposal for easy and quick assessments of the real-time system performance.

Requirement will be met.

4323-3

Controller Positions

The Early Mission Support Room shall include workstations with MOC systems to allow spacecraft monitoring in real time. Controller position capabilities shall include providing

a. Color displays

b. Clock displays

c. Interface devices

d. Voice communication panels

e. Documentation storage

Requirement will be met.

4323-3.1

Color Displays

Each controller position shall have a graphic color display.

Requirement will be met.

4323-3.2

Clock Displays

Each controller position shall have an unobstructed view of the UTC and countdown clock.

Requirement will be met.

4323-3.3

Interface Devices

Each controller position shall have a keyboard and any other input devices necessary to interface with the real-time MOC systems.

Requirement will be met.

4323-3.4

Voice Communications Panels

Each controller position shall have access to a voice communications panel (including handset and headset options, speaker options, and volume control) containing required CCL, SCAMA, and public phone lines.

Requirement will be met.

4323-3.5

Documentation Storage

Each controller position shall have easily accessible storage space for documentation, printouts, and papers.

Requirement will be met.

4400-1

MOC Operations Support

The Triana mission shall use a single MOT and the SMEX MOC operations facilities to support on-orbit and on-ground testing. MOC operations support capabilities shall include the following:

a. Identifying the operational interfacing elements

b. Providing the MOC operational interfaces

Requirement will be met.

4410-1

Operational Interfacing Elements Overview

The operational interfacing elements for the MOC include the USN and DSN ground stations, FDF, TSOC, ISTP/CDHF, PlasMag, Triana Project, I&T GSE, JSC Payload Operations Control Center (POCC), launch site at KSC, NISN, and Nascom.

Requirement will be met.

4410-1.1

Ground Stations

The USN and DSN ground stations shall perform data distribution of telemetry, including file segmentation by virtual channel. The ground stations shall also perform uplink of command loads to the spacecraft.

Requirement will be met.

4410-1.2

Multi-Mission Flight Dynamics

The MMFD shall perform launch vehicle support and early orbit determination and acquisition data generation on a contingent basis.

Requirement will be met.

4410-1.3

Triana Science Operations Center

The TSOC shall perform Earth science planning and science data analysis.

Requirement will be met.

4410-1.4

International Solar-Terrestrial Physics/Central Data Handling Facility

The ISTP/CDHF shall perform space science planning and science data analysis

Requirement will be met.

4410-1.5

Triana Project

The Triana Project shall provide flight software maintenance.

Requirement will be met.

4410-1.6

Integration and Test Ground Support Equipment

I&T GSE shall provide support for spacecraft component and instrument integration and testing.

Requirement will be met.

4410-1.7

Johnson Space Center Remote Payload Operations Control Center

The JSC Remote POCC shall perform all prime flight operations from launch through booster ignition burnout.

Requirement will be met.

4410-1.8

Kennedy Space Center Launch Site

The KSC launch site shall perform activities in support of integration testing, ETE testing, operation simulations, and launch. Voice and data communications are required between the launch site and GSFC.

Requirement will be met.

4410-1.9

NASA Integrated Services Network/NASA Communications

NISN/Nascom provides the voice and data communication circuit interfaces among the supporting elements. Communication services are required to support operations activities during prelaunch, launch, and postlaunch mission operations.

Requirement will be met.

4410-1.10

PlasMag Facility

The PlasMag facility shall perform space science planning and science data analysis for recovered postpass from the MOC.

Requirement will be met.

4420-1

MOC Operational Interfaces

Figure 4420-1 shows the interfaces between the MOC and other operational elements. Detailed support requirements and data transfer formats between the MOC and all external interfaces will be in accordance with the *Interface Control Document (ICD) Between the Triana Ground Data System (GDS), the Triana Project, and the Triana PI.*

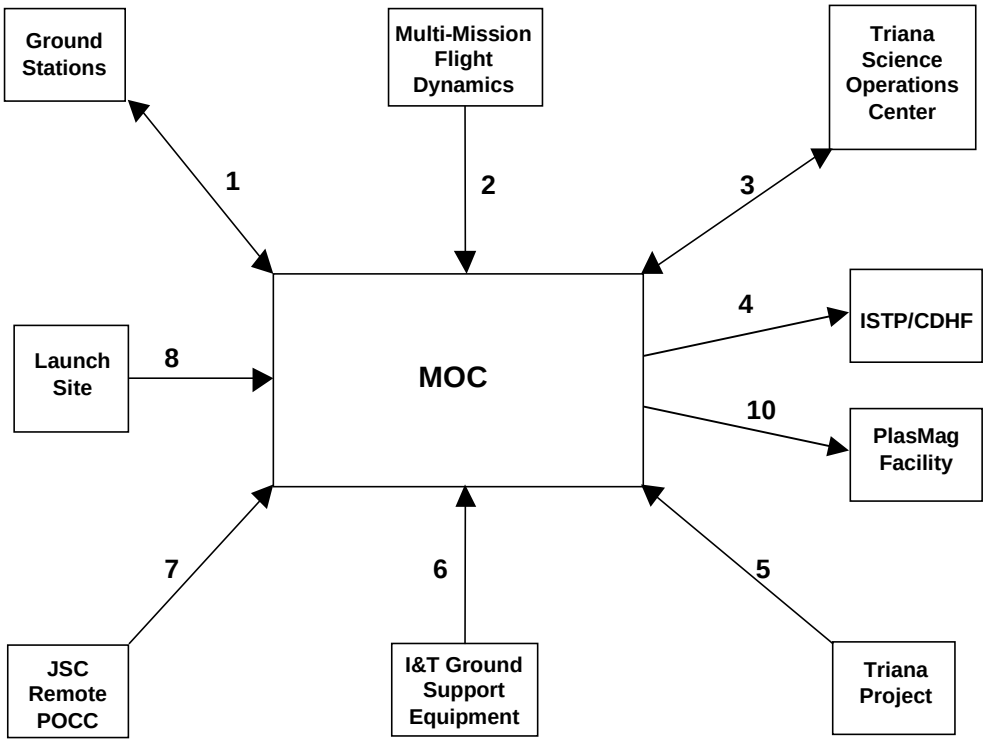


Figure 4420-1: Ground System Functional Interfaces

Requirement will be met.

4420-1.1

Ground Stations Interface

The MOC shall receive stripped VC0, VC1, VC2, VC4, and VC5 telemetry in real time and stripped VC3 telemetry postpass from the ground stations. The MOC shall also receive tracking data from the ground stations. The MOC shall provide command loads to the ground stations for uplink. The MOC shall also provide flight dynamics acquisition data to the ground stations.

Requirement will be met.

4420-1.1.1

The USN ground station shall distribute station status packets to the MOC.

4420-1.2

MMFD Interface

The MOC shall receive orbit determination and acquisition data on a contingent basis from the MMFD.

Requirement will be met.

4420-1.3

TSOC Interface

The MOC shall receive science command scripts from the TSOC. The MOC shall provide VC0, VC2, VC3, and VC4 telemetry; flight dynamics mission planning; and scheduling aids to the TSOC.

Requirement will be met.

4420-1.4

ISTP/CDHF Interface

The MOC shall provide VC0 telemetry in real-time and predictive ephemeris data to the ISTP/CDHF.

Requirement will be met.

4420-1.5

Triana Project Interface

The MOC shall receive flight software loads from the Triana project.

Requirement will be met.

4420-1.6

JSC Remote POCC Interface

The MOC shall receive payload data from the JSC Remote POCC during L&EO and the deployment phases of the mission.

Requirement will be met.

4420-1.7

Launch Site Interface

The MOC shall receive launch site video and payload data during prelaunch and launch.

Requirement will be met.

4420-1.8

NISN/Nascom Interface

The MOC shall use the NISN/Nascom for voice and data communication with the identified operational interfaces.

Requirement will be met.

4420-1.9

PlasMag Facility Interface

The MOC shall provide VC0 telemetry postpass via FTP to the PlasMag facility.

Requirement will be met.

4420-2

SMEX MOC Operations

The SMEX MOC shall provide the capability to perform early mission operations and normal operations.

Requirement will be met.

4420-2.1

Normal Operations

Figure 4420-2 illustrates a nominal real-time operations scenario. At least three 8-hour passes per day will be required to support real-time science, health and safety checks, commanding, and tracking operations. Command loads will be uplinked and verified approximately once per week.

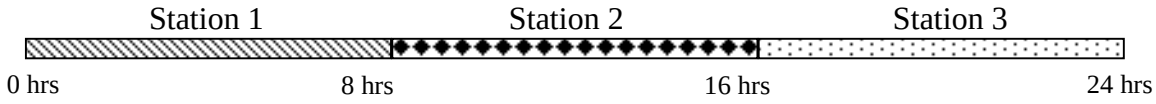


Figure 4420-2: Triana Typical Operations Scenario

Requirement will be met.

4420-2.2

Early Mission Operations

The early mission operations phase of the Triana mission includes prelaunch test and simulations, launch, spacecraft deployment from the Shuttle, booster rocket ignition, cruise to the L1 point, orbit insertion about the L1 point, and final instrument checkout. This is expected to take up to 3 months. Following spacecraft deployment from the Shuttle, the MOC facility will provide spacecraft control, monitoring, and planning, as well as providing the facility for offline processing and performance analysis. It will be used to support real-time activities by providing additional console positions for support personnel. A maximum of 12 workstations must be available during early mission operations, but they are not required to be collocated in a single facility.

Requirement will be met.

5000-1

Summary

NISN shall provide voice and data service interfaces to support Triana operations from prelaunch testing through the launch and postlaunch phases. This function includes voice and data interfaces with the launch site, ground stations, and other ground data system elements.

5100-1

Ground-to-Ground Data Transport Requirements

General and specific NISN requirements are outlined in the subsequent sections.

5100-1.1

Data Service Requirements

Data link requirements that define the services needed to support telemetry, commanding, and transport of miscellaneous data are described in the subsequent sections.

5100-1.1.1

Telemetry Data Services

A flow diagram describing the data services supporting telemetry is shown in Figure 5100-1. In general, the services required are as follows:

a. Data services to support telemetry distribution from the USN NMC in Horsham, Pennsylvania, to GSFC

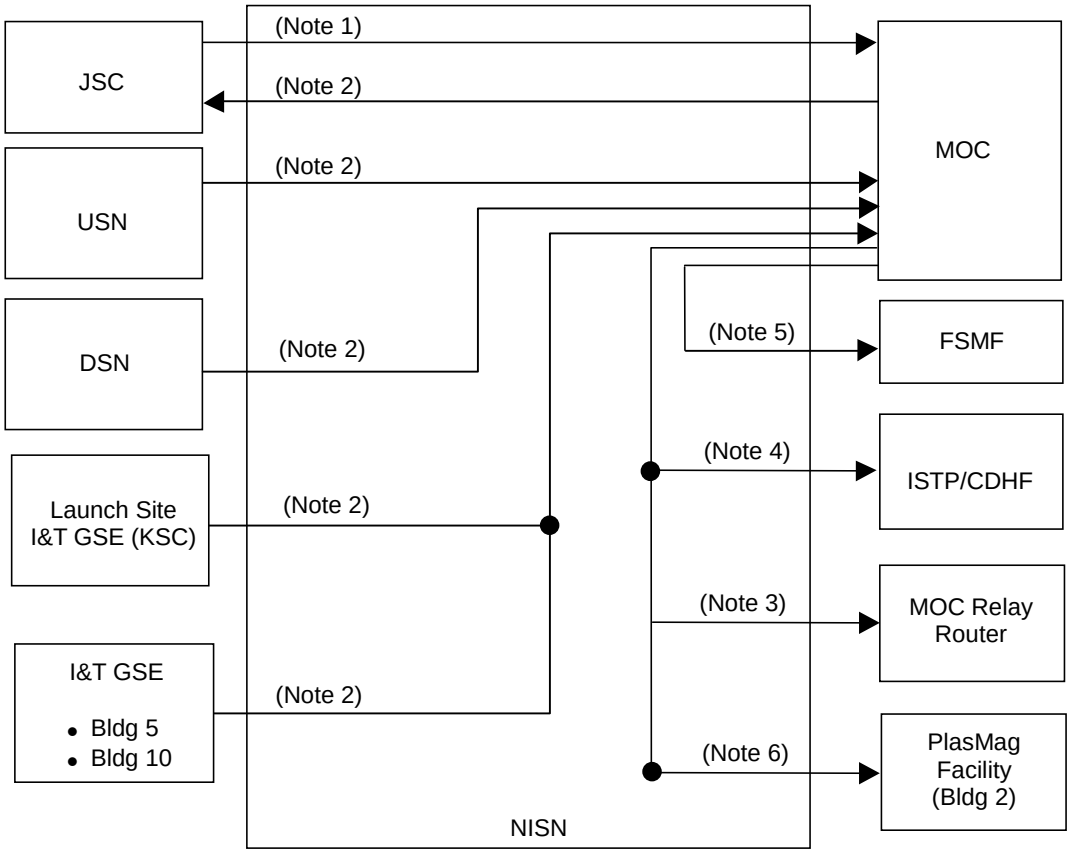
b. Data services to support telemetry distribution from the JPL in Pasadena, California, to GSFC

c. Data services to support telemetry distribution from the launch site (KSC) to GSFC

d. Data services to support low-rate telemetry between the JSC Triana POCC and GSFC MOC

e. Data services to support backup telemetry distribution from the USN NMC in Newport Beach, California, via Horsham, Pennsylvania, to GSFC

f. Data services to support telemetry distribution from the GSFC I&T facility to the GSFC MOC



NOTES

1. Real-time calibrated ancillary system (CAS) data via the Web from JSC to GSFC
2. Support real-time transfers up to 256 kbps, and FTP transfers postpass
3. Real-time and postpass science products
4. Real-time science products
5. Offline image data transfers
6. FTP transfers of replayed PlasMag real-time science

Figure 5100-1: Telemetry Data Services

Requirement will be met.

5100-1.1.2

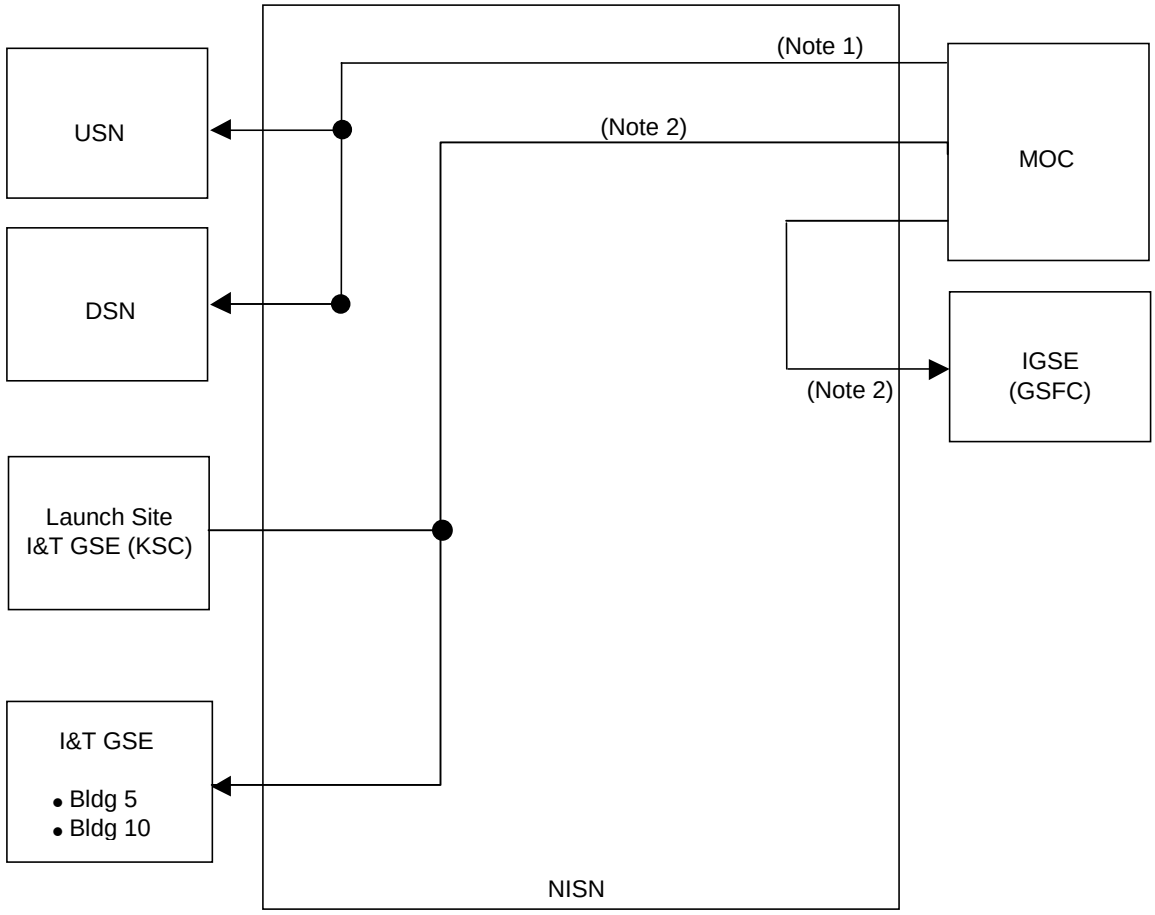
Commanding Data Services

A flow diagram describing the data services that support commanding is shown in Figure 5100-2. In general, the circuits required are as follows:

a. Data services to support commanding from the MOC to all ground sites

b. Data services to support commanding from the MOC to the launch site

c. Data services to support commanding from the MOC to the I&T facilities



NOTES

1. Spacecraft commands
2. Spacecraft commands (I&T only)

Figure 5100-2: Command Data Services

Requirement will be met.

5100-1.1.3

Miscellaneous Data Services

A flow diagram describing the data services supporting the transport of miscellaneous data is shown in Figure 5100-3. Services provided include the following:

a. Data services to support data transfer from/to the MOC and MOC relay router

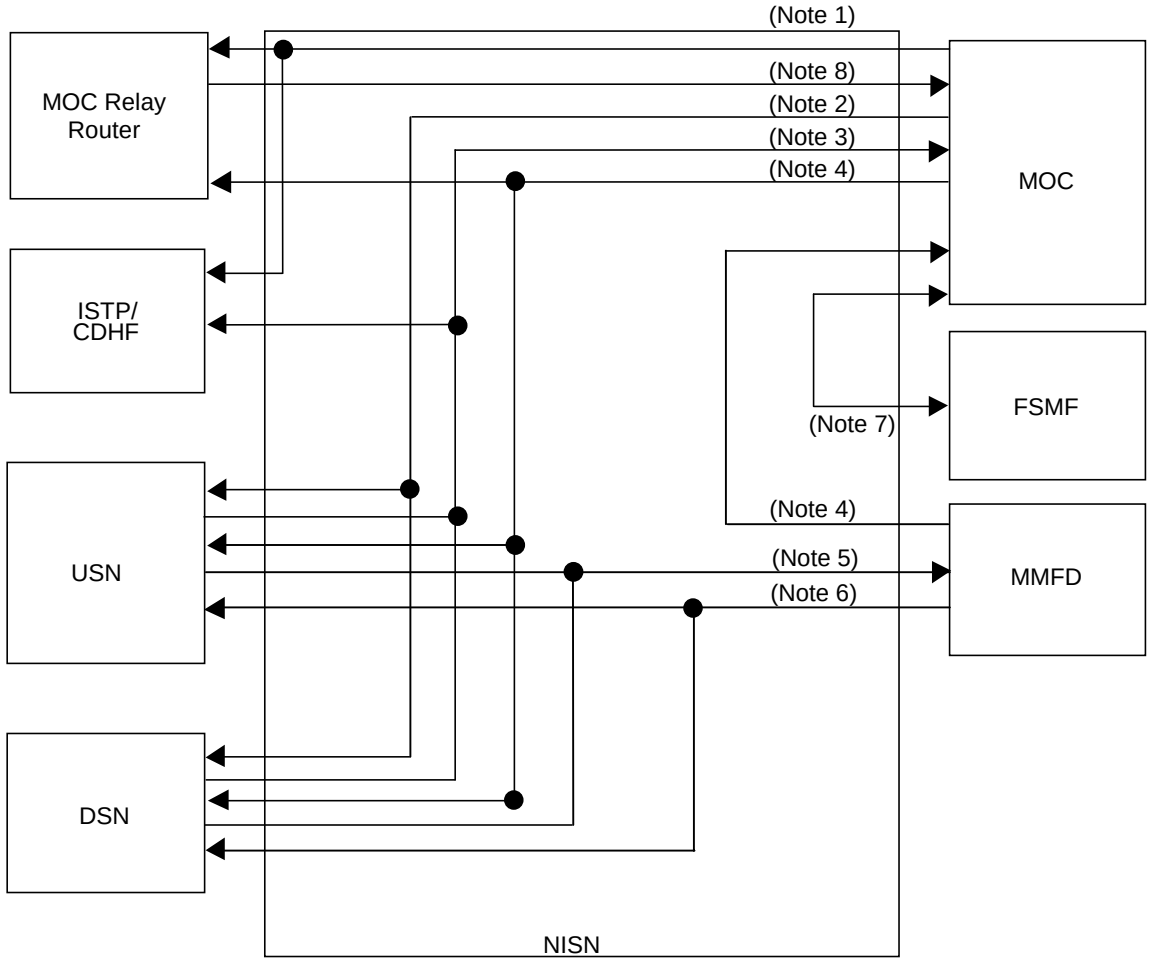
b. Data services to support data transfer from the MOC to the ISTP CHDF

c. Data services to support data transfer from/to the MOC and FSMF

d. Data services to support data transfer from/to the MOC and MMFD

e. Data services to support data transfer from/to the MMFD and USN/NMC

f. Data services to support data transfer from/to the MMFD and DSN



NOTES

1. Administrative reports, pass summaries, command instructions
2. Schedule requests
3. Schedule data
4. Orbit and planning aid data
5. Tracking data
6. Acquisition data
7. Software and table loads
8. Science observation scripts

Figure 5100-3: Data Services: Miscellaneous Data

Requirement will be met.

5100-1.2

Specific Data Service Requirements

Table 5100-1 summarizes the specific data service requirements for Triana.

Item No.	Terminals		Data Type	Data Rate (including overhead)	Delivery Time	Service Date(s) and Duration	Purpose and Remarks
	A	B					
1	NMC/USN	MOC	S/C TLM MOC CMDs	256 kbps 128 kbps ISDN 2 kbps	R/T and postpass R/T	L-11 months to EOM	ISDN is backup service
2	DSN	MOC	S/C TLM MOC CMDs	256 kbps 2 kbps	R/T and postpass R/T	L-9 months to EOM	Real-time CMDs TLM transfers
3	MOC	TSOC	S/C TLM, mission planning aids	VPN	R/T and postpass	L-9 months to EOM	TLM transfers and Level 0 products, FTP of planning aids
4	MOC	ISTP CDHF	S/C TLM	16 kbps	R/T	L-9 months to EOM	TLM transfers
5	MOC	PlasMag Facility (Bldg 2)	Recovered S/C TLM	N/A	FTP	L-9 months to EOM	TLM transfers
6	MOC Relay Router	MOC	Science scripts and mission planning aids	Included in item #3	Offline	L-9 months to EOM	Science scripts file transfer originating from TSOC
7	MOC	FSMF	Image files	N/A	FTP	L-9 months to EOM	
8	FSMF	MOC	Flight S/W, table loads and Images	N/A	Offline	L-9 months to EOM	
9	MMFD	DSN	Tracking/acq data (encapsulated)	9.6 kpbs	R/T	L-9 months to EOM	
10	I&T GSE (Bldg 5)	MOC	S/C TLM MOC CMDs	256 kbps 2 kbps	R/T R/T	L-12 months to launch	I/F with both ETU and flight I&T S/C
11	I&T GSE (Bldg 10)	MOC	S/C TLM MOC CMDs	256 kbps 2 kbps	R/T R/T	L-12 months to launch	I/F with flight I&T S/C during thermal vacuum
12	I&T GSE (KSC launch site)	MOC	S/C TLM MOC CMDs	256 kbps 2 kbps	R/T R/T	L-6 months through ascent operations	I/F with S/C during launch readiness testing
13	Triana ETU (Bldg 1)	MOC	S/C TLM MOC CMDs	256 kbps 2 kbps	R/T R/T	L-12 months to launch	I/F with ETU

Item No.	Terminals		Data Type	Data Rate (including overhead)	Delivery Time	Service Date(s) and Duration	Purpose and Remarks
	A	B					
14	USN Scheduling Center Horsham, PA	MOC	Scheduling data	Included in item #1	Offline	L-9 months to EOM	For MOT support scheduling
15	DSN Scheduling Center	MOC	Scheduling data	Included in item #2	Offline	L-9 months to EOM	For MOT support scheduling
16	MOC Relay Router	MOC	Admin	Included in item #3	Offline	L-9 months to EOM	E-mail via TSOC
17	MOC	I&T GSE (KSC launch site)	CMD	2 kbps	R/T	L-6 months through launch	MOC CMD I/F for launch readiness testing
18	JSC	MOC	S/C TLM	256 kbps	R/T	L-6 months to WOW	GSFC I/F for TLM data from JSC
19	MOC	JSC	S/C TLM	256 kbps	R/T	L-6 months to WOW	GSFC I/F for TLM data to JSC
20	JSC	MOC	CAS	Internet	R/T	L-6 months to WOW	GSFC I/F for TLM data to JSC

Table 5100-1: Data Service Requirements

Requirement will be met.

5100-2

Ground-to-Ground Voice Service Requirements

General and specific voice service requirements are defined in the subsequent sections.

Requirement will be met.

5100-2.1

General Voice Service Requirements

General voice service requirements are to provide voice services between GSFC elements and the following:

a. USN NMC

b. Launch site

c. Internal GSFC elements

d. DSN

Requirement will be met.

5100-2.2

Specific Voice Service Requirements

Table 5100-2 summarizes the specific voice service requirements for the Triana mission.

Item No.	Terminals		Service Date(s) and Duration	Purpose and Remarks
	A	B		
1	MOC	NMC/USN	L-11 months to EOM	(Black phone)
2	MOC	DSN	L-9 months to EOM	
3	MOC	FDF	L-9 months to EOM	
4	MMFD	DSN	L-9 months to EOM	
5	I&T GSE (Bldg 5)	MOC	L-12 months to launch	
6	I&T GSE (Bldg 10)	MOC	L-12 months to launch	
7	I&T GSE (KSC launch site)	MOC	L-6 months through ascent operations	
8	JSC	MOC	L-9 months to WOW	

Table 5100-2: Voice Service Requirements

Requirement will be met.

6000-1

ITOS Science Data Processing Summary

The Integrated Test and Operations System (ITOS) is responsible for the science data processing of Triana spacecraft data (science and/or housekeeping). Science data processing includes real-time processing as well as postpass processing. The ITOS will provide all interfaces to the GDS elements required to support spacecraft I&T, L&EO, and on-orbit operations. The ITOS will support the data rates, data volume, command and telemetry structure, and timetag information specified by Sections 2005 and 2020 of this DMR.

The ITOS will create Triana science products to be transmitted to the Triana PI at the TSOC located at the Scripps Institute for Oceanography in La Jolla, California, and the ISTP CDHF located at GSFC. The first product is real-time science data from the PlasMag instrument complement. ITOS will transmit, within 3 seconds of receipt, PlasMag CCSDS packets from VC0 to the ISTP CDHF. The packets will be forwarded to the ISTP CDHF in the order they are received from the ground station. PlasMag packets will be identified by their application process IDs (APIDs) documented in the MOC/PlasMag Operations Agreement (OA).

The second science product is real-time science data from the NISTAR instrument. ITOS will transmit, within 3 seconds of receipt, NISTAR CCSDS packets from VC0 to the TSOC. The packets will be forwarded to the ISTP CDHF in the order they are received from the ground station. NISTAR packets will be identified by their APIDs documented in the MOC/TSOC OA.

The third science product is real-time image data from the EPIC instrument. ITOS will collect real-time EPIC visible light (RGB) image data from VC2 and aerosol image data from VC4 at the CCSDS transfer frame level, remove the transfer frame headers and trailer, concatenate the data from each frame into a single image, and FTP the completed image to TSOC. Ancillary onboard processing information appearing in the first line of each image is also included at the beginning of each image to the TSOC. The images will be forwarded to the TSOC in the order they are received from the ground station.

The fourth science product is recorded image data from the EPIC instrument. Recorded EPIC image data downlinked in VC3 is received at the ground station and stored. Upon completion of the station’s pass, the station will FTP the VC3 file to the MOC. ITOS will collect the EPIC VC3 image data files at the CCSDS transfer frame level, remove the transfer frame headers and trailer, concatenate the data from each frame into a single image, and FTP the completed image to the TSOC. Ancillary onboard processing information appearing in the first line of each image is also included at the beginning of each image to the TSOC. The images will be forwarded to the TSOC in the order they are received from the ground station.

Requirement will be met.

6100-1

Input – Ground Station

The ITOS shall support receipt of data from the ground station.

6100-1.1

Data Dumps

The ITOS shall be able to capture continuous real-time engineering and science telemetry and up to four postpass file transfers of engineering and science telemetry per day during normal operations. Each station shall transfer files using one file per virtual channel.

Requirement will be met.

6100-1.2

Postpass Data

The ITOS shall support receipt of postpass data in SMEX telemetry format from USN ground stations and in SFDU format from DSN ground stations.

Requirement will be met.

6100-1.3

Retransmissions
The MOT shall request any necessary retransmissions from the ground station within 7 days of original spacecraft contact.

Requirement will be met.

6100-1.4

Data Volume

The ITOS shall be able to capture up to 3 gigabytes per day.

Requirement will be met.

6100-2

Input – MOC

The ITOS shall support receipt of postpass data in file format from USN and DSN using FTP over an IP interface.

Requirement will be met.

6100-3

Output – PI Science Facility

The ITOS shall support the transmission of real-time science products to the Triana PIs using TCP/IP protocol and postpass science products in file format via FTP.

Requirement will be met.

6100-3.1

Delivery Verification

The ITOS shall provide a mechanism whereby PI facilities can determine whether all files of a product have been delivered.

Requirement will be met.

6200-1

General

The ITOS shall provide the capability for generating real-time and postpass science processed data.

Requirement will be met.

6200-1.1

Format

Data set construction shall include a metafile and conform to the format described in the Triana Project/PI/GDS ICD.

Requirement will be met.

6200-1.2

Information

The ITOS shall include packets, packet quality and accounting information, and image data file quality and accounting information as specified in the Triana Project/PI/GDS ICD.

Requirement will be met.

6200-2

VCIDs and Data Formats

The ITOS shall receive discrete virtual channel data:

a. VC0 = Real-time spacecraft engineering, NISTAR science, and PlasMag science in CCSDS packet format

b. VC1 = Recorded spacecraft engineering in CCSDS packet format

c. VC2 = Real-time EPIC image telemetry containing RGB data in EPIC image format

d. VC3 = Real-time EPIC image telemetry in EPIC image format delivered postpass via FTP

e. VC4 = Real-time EPIC image telemetry containing aerosol data in EPIC image format

f. VC5 = Table/memory file dumps

Requirement will be met.

6200-3

Postpass Science Data Performance

Under normal operating conditions, postpass science image data files (VC3) shall be available for transfer to the required destinations within 2 hours of ITOS receipt and replay of the last data contained in the image data files.

Requirement will be met.

6200-4

Production Data Processing

The ITOS shall perform quality checks and process the data as first-in-first-out (FIFO) order. The USN ground stations shall ensure that data is forwarded to ITOS in time order with redundant data removed prior to transmission to ITOS. Data received from DSN will be managed so that duplicate data due to station handovers will not be transmitted to ITOS.

Requirement will be met.

6200-4.1

Real-Time Packet Selection

Real-time ITOS data transmission to PIs shall be based on the spacecraft ID (SCID), APID and VCID.

Requirement will be met.

6200-4.1.1

The ITOS shall provide the capability to support real-time data transmission from up to 256 APIDs per VCID to 3 destinations simultaneously.

Requirement will be met.

6200-4.2

Packet Ordering

There are no ITOS packet-ordering requirements for real-time data transmissions.

Requirement will be met.

6200-4.3

Redundancy Removal

The USN ground stations will handle station handovers such that only one real-time data stream from one station is forwarded to ITOS. The MOT will manage DSN station interfaces to avoid multiple simultaneous ground station transmissions to ITOS. ITOS is

not required to provide the capability to identify redundant packets by comparing APID, packet sequence counters, and packet times.

Requirement will be met.

6200-4.4

Quality and Accounting

The ITOS shall calculate and report the total number of packets received for each ground station session.

Requirement will be met.

6200-4.4.1

The ITOS shall provide the quality and accounting information for each output image data file.

Requirement will be met.

6200-4.4.2

The ITOS shall notify operations personnel at the start and completion of image data file construction.

Requirement will be met.

6200-4.4.3

The ITOS shall provide the capability to analyze problem data offline.

Requirement will be met.

6200-4.5

Record Keeping

The ITOS shall maintain a record of all image data files generated during the normal science capture and process phase of the mission.

Requirement will be met.

6200-4.6

Replay Data

The ITOS shall provide the capability to create image data files from previously acquired data.

Requirement will be met.

6200-5

The ITOS shall provide the capability to generate data files containing all packets received between two relative times in the secondary packet header field for VC0 and VC1 telemetry or an image header field for VC2, VC3, and VC4 telemetry.

Requirement will be met.

6200-6

Data Distribution

Distribution of real-time science data shall be according to Table 6200-1.

Data Type	Data Source	Processing Frequency	Data Destinations	Data Ready Time
Real-time spacecraft engineering data (VC0)	ETU or spacecraft	Per test schedule	Science IGSE, ISTP CDHF, and TSOC at Scripps	Within 3 seconds
	Ground stations	L&EO/deployment/ cruise/orbit insertion – continuous	Science IGSE (SMEX MOC), ISTP CDHF, and TSOC at Scripps	Within 3 seconds
		Normal operations – continuous	ISTP CDHF and TSOC at Scripps	Within 3 seconds
Real-time spacecraft science image data (VC2 and VC4)	ETU or spacecraft	Per test schedule	Science IGSE and TSOC at Scripps	Within 2 minutes
	Ground stations	L&EO/deployment/ cruise/orbit insertion – continuous	Science IGSE (SMEX MOC) and TSOC at Scripps	Within 2 minutes
		Normal operations – continuous	TSOC at Scripps	Within 2 minutes

Table 6200-1: Real-Time Data Distribution – Based on VC0, VC2, and VC4 Data

Requirement will be met.

6200-7.1

Transmissions

The ITOS real-time data transmissions shall be initiated automatically consistent with the operations requirements of the TSOC and ISTP CDHF.

Requirement will be met.

6200-8

Postpass File Processing

The ITOS shall process postpass image files in the order the data is received in the file. Time-ordering and redundant data removal by ITOS is not required.

Requirement will be met.

6200-8.1

EPIC Image Processing

The ITOS shall remove the CCSDS transfer frame headers and trailer from VC3 image data and concatenate the series of image data segments necessary to construct a full EPIC image.

Requirement will be met.

6200-9

Postpass Data Distribution

Distribution of postpass processed data files shall be according to Table 6200-2.

Data Type	Data Source	Processing Frequency	Data Destinations	Data Ready Time
Recorded spacecraft engineering telemetry (VC1)	ETU or spacecraft	Per test schedule	Science IGSE (SMEX MOC), TSOC at Scripps, and ISTP CDHF on request	Within 2 hours
	Ground Stations	L&EO/deployment/ cruise/orbit insertion – three 8-hour passes per day	Science IGSE (SMEX MOC), TSOC at Scripps, and ISTP CDHF on request	Within 2 hours
		Normal operations – three 8-hour passes per day	TSOC at Scripps and ISTP CDHF on request	Within 2 hours
Recorded EPIC science telemetry (VC3)	ETU or spacecraft	Per test schedule	Science IGSE (SMEX MOC) and TSOC at Scripps	Within 2 hours
	Ground Stations	L&EO/deployment/ cruise/orbit insertion – three 8-hour passes per day	Science IGSE (SMEX MOC) and TSOC at Scripps	Within 2 hours
		Normal operations – three 8-hour passes per day	TSOC at Scripps	Within 2 hours

Table 6200-2: Routine Data Distribution – Based on VC1 and VC3 Data

Requirement will be met.

6200-9.1

Transmissions

The ITOS postpass data file transmissions shall be initiated automatically consistent with the operations requirements of the TSOC.

Requirement will be met.

6300-1

ITOS Data Retransmission Request

All retransmissions requests shall be provided as postpass data files.

Requirement will be met.

6300-1.1

Raw Telemetry

The ITOS shall be able to reprocess data sets from raw telemetry if requested after the 30-day online retention period.

Requirement will be met.

6300-1.2

Processed

The ITOS shall be able to retransmit processed data files that are stored online within 72 hours.

Requirement will be met.

6300-1.3

Retransmissions

All retransmitted data files will be re-sent in their original form.

Requirement will be met.

6300-2

Raw Data Online

The ITOS shall be capable of storing raw data online for up to 30 days.

Requirement will be met.

6300-2.1

Storage

The ITOS shall be capable of storing up to 45 gigabytes of received raw telemetry online.

Requirement will be met.

6300-3

Long-Term Raw Data Storage

The ITOS shall support the capability for 30-day storage of raw data.

Requirement will be met.

6300-3.1

Recording

The ITOS shall be capable of archiving received transfer frames and packets.

Requirement will be met.

6300-3.2

Processing

The ITOS shall be capable of processing recorded transfer frames and packets.

Requirement will be met.

6300-4

Long-Term Processed Data Storage

The ITOS shall support the capability for 3-day storage of processed data files.

Requirement will be met.

6300-4.1

Recovery

The ITOS shall be capable of recovering processed data files from a backup media.

Requirement will be met.

6300-4.2

Recovered Distribution

The ITOS shall be capable of distributing recovered recorded data files.

Requirement will be met.

7000-1

Orbit and Attitude Support

The FDSS will provide attitude determination, attitude control, and trajectory support in the MOC. Support will include attitude determination, sensor evaluation, sensor calibration, trajectory determination and error analysis, maneuver planning and execution, onboard computer verification, and network support. Support will be provided for prelaunch data flows and preparation, L&EO, spacecraft checkout, normal operations, contingency operations, and end-of-mission (EOM) analysis. Orbit and attitude support capabilities shall include providing:

a. Attitude determination and control support

b. Trajectory support

c. Maneuver planning and execution

Additional L&EO, deployment, cruise, orbit insertion and contingency support will be supplied by the MMFD group as necessary. This support may include early orbit determination, early mission acquisition data generation, and transmission to appropriate sites.

Requirement will be met.

7100-1

Attitude Determination and Control Support

The FDSS shall provide attitude determination and control support, including attitude determination, sensor monitoring, and sensor calibration support. Attitude telemetry will be forwarded to the FDSS via ITOS. All attitude products are generated with a J2000 reference coordinate system. Attitude determination and control support capabilities shall include providing

a. Attitude determination

b. Attitude sensor evaluation, calibration, and alignment

c. Control system performance

Requirement will be met.

7110-1

Attitude Determination

The FDSS shall provide attitude determination for verification of the onboard attitude. Attitude determination capabilities shall include providing attitude determination and verification.

Requirement will be met.

7111-1

Attitude Determination and Verification Overview

The FDSS shall verify the onboard attitude through comparison with a ground-generated attitude.

Requirement will be met.

7111-2

Attitude Determination and Verification Product

The FDSS shall generate an electronic report detailing the attitude comparison. The report shall be generated for the MOT and for transfer to the TSOC and ISTP CDHF as needed.

Requirement will be met.

7111-3

Attitude Determination and Verification Accuracy

The FDSS shall produce an attitude solution within .05 degree (3 sigma) for the X-, Y-, and Z-axes relative to the star tracker frame.

Requirement will be met.

7120-1

Attitude Sensor Evaluation, Calibration, and Alignment

The FDSS shall provide sensor evaluation and gyro calibration to assist in assessing spacecraft health and safety and to meet the attitude estimation error budget.

Requirement will be met.

7121-1

Gyro Calibration Overview

The gyro calibration support shall consist of providing a gyro alignment/scale factor adjustment matrix and gyro basis. The FDSS gyro calibration accuracy will be dependent upon the approved gyro calibration maneuvers.

Requirement will be met.

7121-2

Gyro Calibration Product

The FDSS shall generate an electronic report in the SMEX/WIRE format for the MOT as needed.

Requirement will be met.

7121-3

Gyro Calibration Accuracy

The FDSS shall produce gyro calibration consistent with the attitude determination accuracy of .05 degree (3 sigma) for the X-, Y-, and Z-axes relative to the star tracker frame.

Requirement will be met.

7130-1

Control System Performance

The FDSS shall compare the target quaternions from telemetry with the ground attitude solution. The output shall be a file containing mean errors per axis, standard deviation of errors per axis, and maximum errors as well as the number of points over the maximum allowed error. The FDSS report will be provided to the MOT as needed.

Requirement will be met.

7200-1

Trajectory Support

The FDSS and MMFD shall provide trajectory support, including orbit determination, orbital ephemeris data generation, station coverage predictions, lunar ephemeris and Sun angle predictions, orbit event predictions, and maneuver planning and execution. Trajectory support capabilities shall include providing

a. Trajectory determination and error analysis

b. Onboard computer (OBC) support processing and verification

c. Network support

d. Maneuver planning and execution support

Requirement will be met.

7210-1

Trajectory Determination and Error Analysis

Trajectory determination and error analysis capabilities shall include the following:

a. Predicted state vector

b. Predicted and definitive orbit ephemeris data

c. Ground station coverage predictions

d. Lunar ephemeris predictions

e. Sun angle predictions

f. Orbit event predictions

Requirement will be met.

7211-1

Predicted State Vector Overview

The FDSS and MMFD shall provide predicted state vectors for uplink to the onboard orbit propagator.

Requirement will be met.

7211-2

Predicted State Vector Product

The FDSS and MMFD shall generate a spacecraft uplink vector. The vector shall be generated for use by the onboard orbit propagator. During normal operations, the vector shall be generated at least 24 hours prior to epoch. The system shall have the capability to update epochs upon user request.

Requirement will be met.

7211-3

Predicted State Vector Accuracy

Except during the cruise and orbit insertion phases, the FDSS and MMFD shall produce a vector that will maintain OBC orbit knowledge to within 100 km after 10 days of onboard propagation.

Requirement will be met.

7212-1

Predicted and Definitive Orbital Ephemeris Data Overview

The FDSS and MMFD shall provide predicted and definitive orbital ephemeris data from tracking data from ground stations that is a minimum of 20 minutes of tone ranging (10 minutes from two different stations) and 16 hours of two-way Doppler.

Requirement will be met.

7212-2

Predicted and Definitive Orbital Ephemeris Data Products

The FDSS and MMFD shall generate predicted and definitive orbital ephemeris data products in the J2000 coordinate reference system for both the PlasMag PI and TSOC. The FDSS and MMFD will also generate an electronic report detailing a comparison of the predicted ephemeris to the definitive ephemeris data.

Requirement will be met.

7212-3

Predicted and Definitive Orbital Ephemeris Data Accuracy

The FDSS and MMFD shall produce a predicted orbital data product with an accuracy of 50 km and a definitive orbital data product with an accuracy of 50 km.

Requirement will be met.

7213-1

Ground Station Coverage Predictions Overview

The FDSS and MMFD shall provide ground station coverage predicts for mission planning and ground station scheduling purposes. The predicts shall include acquisition of signal (AOS), LOS, maximum elevation, and station masking.

Requirement will be met.

7213-2

Ground Station Coverage Predictions Product

The FDSS and MMFD shall generate an electronic report detailing the ground station coverage predicts. The report shall be generated for the MOT and for transfer to the TSOC, USN, and DSN. The report shall be transferred weekly and contain a 4-week period prediction.

Requirement will be met.

7213-3

Ground Station Coverage Predictions Accuracy

The FDSS and MMFD shall produce ground station coverage predicts accurate to 50 km after 10 days.

Requirement will be met.

7214-1

Lunar Ephemeris Predicts Overview

The FDSS and MMFD shall provide lunar ephemeris predicts for mission planning and spacecraft performance monitoring.

Requirement will be met.

7214-2

Lunar Ephemeris Predicts Product

The FDSS and MMFD shall generate an electronic report detailing lunar ephemeris predicts. The report shall be generated for the MOT and for transfer to the TSOC. Four-week predicts shall be available for the TSOC and MOT. Reports shall be transferred weekly.

Requirement will be met.

7214-3

Lunar Ephemeris Predicts Accuracy

The FDSS and MMFD shall produce lunar ephemeris predicts consistent with orbit determination accuracy.

Requirement will be met.

7215-1

Sun Angle Predicts Overview

The FDSS and MMFD shall provide Sun angle predicts for spacecraft performance monitoring.

Requirement will be met.

7215-2

Sun Angle Predicts Product

The FDSS and MMFD shall generate an electronic report detailing the Sun angle predicts. The report shall be generated for the MOT and for transfer to the TSOC. The report shall be transferred 1 week prior to launch, and weekly thereafter. The report shall contain a 4-week predict.

Requirement will be met.

7215-3

Sun Angle Predicts Accuracy

The FDSS and MMFD shall produce Sun angle predicts consistent with orbit determination accuracy.

Requirement will be met.

7216-1

The FDSS and MMFD shall provide orbit event predictions for mission and science planning purposes.

Requirement will be met.

7216-2

Orbit Event Predictions Product

The FDSS and MMFD shall produce orbit event predictions consistent with the requirement to predict the range and Sun-Earth-spacecraft angle values. The reports shall be generated for the MOT and for transfer to the TSOC. The reports shall be transferred weekly and will contain a 4-week prediction.

Requirement will be met.

7216-3

Orbit Event Predictions Accuracy

The FDSS and MMFD shall produce orbit event predictions consistent with orbit determination accuracy.

Requirement will be met.

7220-1

Onboard Computer Support Processing and Verification

The FDSS and MMFD shall provide OBC support processing and verification to assist in assessing the spacecraft health and safety. OBC support processing and verification capabilities shall include orbit propagation validation.

Requirement will be met.

7221-1

OBC Orbit Propagation Validation Overview

The FDSS and MMFD shall verify the OBC orbit propagator performance through comparison with a ground-based orbit propagator.

Requirement will be met.

7221-2

OBC Orbit Propagation Validation Product

The FDSS and MMFD shall generate an electronic report detailing the OBC orbit propagator performance. The report shall be generated for the MOT as needed.

Requirement will be met.

7221-3

OBC Orbit Propagation Validation Accuracy

The OBC MMFD orbit knowledge shall be maintained within 100 km over a 10-day propagation period.

Requirement will be met.

7230-1

Network Support

The FDSS and MMFD shall provide network support for acquiring the spacecraft during ground contacts. Network support capabilities shall include improved interrange vector (IIRV) acquisition data for USN and DSN's 26-meter sub-net. Document 820-013, TRK 2-17 shall be used by MMFD as the IIRV format of acquisition data delivered to the DSN. SPICE/SPK per Document 820-013, TRK 2-33 shall be used for acquisition data for DSN's 34-meter sub-net and will be provided by MMFD.

DSN Response: Accepted. (The DSN does not now possess SPK interface capability, but is in the process of implementing it; the expected, but not committed to, implementation complete date is mid-2000.)

MMFD Response: Requirement will be met.

7231-1

IIRV Acquisition Data Overview

The FDSS and MMFD shall provide acquisition data in the form of IIRVs in geocentric rotating coordinates. The acquisition data will be generated prelaunch and updated weekly during the nominal operations phase. During the first 24-hours of the mission, these data will be updated after each MCC. During the cruise phase, they will be updated weekly and after each MCC.

Requirement will be met.

7231-2

IIRV Acquisition Data Product

The FDSS and MMFD shall provide USN and DSN an electronic report spanning a minimum 10-day period.

Requirement will be met.

7240-1

Maneuver Planning and Execution Support

The Guidance Navigation Control (GNC) located in the FDSS shall provide Delta-V maneuver planning and execution support for all phases of the Triana mission. Products shall be provided to the MOT include the following:

a. Maneuver execution plan for each spacecraft maneuver

b. Postmaneuver report evaluating thruster performance and containing a fuel remaining estimate and predicted versus actual performance using real-time pressure and temperature thruster data

Requirement will be met.

7240-2

Cruise and Orbit Insertion Support

The GNC shall provide maneuver planning and execution support during the cruise phase to support the Delta-V burns. The L1 Lissajous orbit insertion maneuver will be supported to achieve an orbit about the L1 point.

Requirement will be met.

7240-3

Nominal Support

The GNC shall provide maneuver planning and execution support for all station keeping maneuvers once the spacecraft is in its Lissajous halo orbit. The frequency of these maneuvers is nominally once per 3 months.

Requirement will be met.